Hydro-Electric Methods in Medicine.

W. S. HEDLEY, M.D.

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THE HYDRO-ELECTRIC METHODS IN MEDICINE

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BY

W. S. HEDLEY, M.D.

IN CHARGE OF THE ELECTRO-THERAPEUTIC DEPARTMENT OF THE LONDON HOSPITAL

WITH ILLUSTRATIONS

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PREFACE.

To the first edition of "Hydro-electric Methods" there were added a historical retrospect, and other chapters not always having any very intimate connection with the main subject of the book. These are now omitted. But inasmuch as the employment of electric lighting currents applied to the body by means of the Water Bath has come to form a very distinguishing feature of the electro-therapeutics of the day, the chapter on "Current from the Main" has been very materially extended and published in a separate form.*

In certain diseases of children—infantile paralysis, some toxic paralyses, nocturnal incontinence of urine and notably in rickets (Segretti)—in infantile paralysis (Lewis Jones)—in certain diatheses, gout, rheumatism, obesity, diabetes, eczema (Gautier and Larat)—the results of systematic hydro-electric treatment have recently been recorded. The methods in question therefore deserve the closer study now that they are found to fill a wider sphere of usefulness.

In connection with a recently advocated thermal treatment of diseases of the heart it may be opportune to remember that the hydro-electric bath in proper hands claims to be an excellent method of dealing not only with cardiac affections of nervous origin but also with conditions where valvular lesions are actually present. Acting as a general tonic and probably in other ways it may be expected to strengthen the systole, to increase arterial tension and diuresis, to decrease the frequency of the pulse, to diminish the bronchial catarrh and œdema or other conditions due to venous stasis (Bruchetti). It must admit its inability to restore a degenerated myocardium; but even an eight minutes' immersion in warm water to which common salt and calcium chloride have been liberally added, has hardly as yet laid claim to this.

The writer takes this opportunity of expressing his thanks to Robt. C. Quin, Esq., for much valuable assistance, especially in the preparation of Tables III. and IV., and the calculations connected with Figs. 7 and 8.

May, 1896.

* "Current from the Main," by W. S. Hedley, M.D. London: H. K. Lewis, 1896.

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THE

HYDRO-ELECTRIC METHODS IN MEDICINE.

INTRODUCTION.

Against the hydro-electric methods, more perhaps than against any other form of electrical treatment, has been levelled the charge of empiricism. And not without reason. Never having been adequately investigated, their real power is but little known and their real province but little understood ; neither is their employment based on any sufficient experimental data. As evidence of this may be instanced the loose and hap-hazard way in which that commonest and best of these methods, the hydro-electric bath, is commonly prescribed and administered. Without guiding principles underlying a rational procedure, it is not surprising that this and allied forms of treatment have hitherto failed to secure due scientific recognition. This neglect, as well as an admitted therapeutic usefulness, is their claim to attention now.

Under the influence of recent views there seems a widening field for hydro-electric methods. No longer limiting itself to strictly local applications, modern

practice avails itself of those procedures whose aim it is to influence the entire organism. "L'electrisation localisée," the watchword of Duchenne, is no longer adequate. It opens up only half the field of electro-therapeutics. Instead of a strict and exclusive localisation it is a widely diffused or *generalised* action that is now more often aimed at in applying electrical energy to the living body. A glance at the field of strictly modern work affords evidence of this. Guided by the experiments of d'Arsonval, it has been clinically demonstrated by Gautier and Larat, and further proved by an experience now familiar to many, that diseases due to a failure or perversion of nutrition ("maladies par ralentissement de nutrition"—Bouchard) are amenable to modern currents and hydro-electric methods. In point of fact it is a matter of every-day practice to treat gout, rheumatism, obesity, diabetes, and many so-called diatheses by sinusoidal or allied forms of current applied through the medium of the water bath. It is evident that the latter, better than any other (non-static) procedure, must deserve the name of "general electrisation." If then it can be shown that by their means electrical treatment can be rationally and accurately administered, the methods in question become entitled to take rank with other scientific procedures, and to rank first where they present advantages special to themselves.

Of hydro-electric methods, the bath occupies the foremost place. It stands first not only on account of its own intrinsic merits, but also in virtue of a very respectable antiquity. This is not the place to

turn aside into the tempting by-paths of archæology, even for the purpose of tracing the evolution of the electric bath, but it may be pointed out that more than a thousand years ago there is evidence that South African mothers were in the habit of dipping their children into pools of water where electric fishes swam, and well-nigh a thousand years before that, Roman physicians probably treated gout in a similar and perhaps in a much less primitive way.*

To gain a standpoint from which to study the rational employment of the electric bath in medicine, the first step in the present inquiry must be an experimental investigation of the *electrical* conditions that have to be encountered.

* Too many clever electricians have shared the fate of Tullus Hostilius, who, according to the Roman myth, incurred the wrath of Jove for practising magical arts, and was struck dead by a thunderbolt. In modern language he was simply working with a high intensity current, and inadvertently touching a live wire, got a fatal shock (Prof. Crookes).

CHAPTER I.

THE PHYSICS OF THE HYDRO-ELECTRIC BATH.

More than once during recent years the present writer has tried by direct experiment to throw light upon some of the physical and physiological problems that present themselves in connection with the therapeutic use of the hydro-electric bath. With a growing experience and improved methods of investigation, his opinions have from time to time undergone modification. But his latest experiments point to conclusions in startling contrast with many preconceived ideas. It is not that previous experimental data have proved inaccurate, but rather (1) that the deductions drawn therefrom do not always seem to be warranted by a fuller knowledge of facts; (2) that these data have in some instances been arrived at by methods which it would now appear are in themselves inherently faulty.

The problem is this: With a given current running through a given bath what proportion of such current will find its way through the body of the immersed patient? In answer to this question various estimates have been hazarded ranging between 5 per cent. and 20 per cent. of the total current. It is obviously a question of the relative resistance of the bath water and of the immersed body. Many different

"values" have been given to the resistance of the latter. The only point upon which all observers seem to agree is the adoption of the Wheatstone Bridge method as the best means of measuring the resistance of the bath. It is in this fact that an explanation of the above discrepancies is very probably to be found. It has been contended that the "fluid all-round" contact when the body is immersed complicates this question beyond all ordinary problems of electrical resistance. But inasmuch as the body under these conditions becomes part of a composite conductor, it is evident that it must take its share of current according to definite physical laws. It is in the latter, therefore, and in them only, that an answer to the question must be sought.

So far as the present question is concerned, it would appear correct to define "resistance" as the algebraic sum of all the forces opposing the current. This value has been taken in all the following tests. Now assuming in an electrolytic circuit, such as the bath, the correctness of the above definition of resistance, what are its component parts? (1) the "back" electromotive force; (2) the ohmic resistance. With regard to the former, it is a negative quantity, and should be deducted from the "impressed" electromotive force, giving what might be conveniently termed the "effective" electromotive force. For instance, if the ohmic resistance be taken to equal 100, and the "impressed" E.M.F. to be ·6, and the "back" E.M.F. to be ·5, then the current would equal $\frac{\cdot 6 - \cdot 5}{100} = 1$ milliampère, and the apparent or

total resistance 600 ohms. Again, under the same conditions, but with an impressed E.M.F. of 10, the current would be $\frac{10-\cdot5}{100}$ = 95 milliampères, and the apparent or total resistance would be 105 ohms. Turning to the second factor—the ohmic resistance—is this a constant quantity? When a current is passed through an electrolyte, decomposition takes place. When the electrolyte is water, hydrogen and oxygen are liberated; and the rate of their evolution depends upon the rate of current flow (ampères). Now, apart altogether from the opposing E.M.F. between these gases and the electrodes, the specific ohmic resistance of these gaseous electrolytic envelopes is greater than that of the water. From this cause there will occur a slight increase of ohmic resistance, as the current density becomes greater. But in order to increase the current it is necessary to raise the impressed E.M.F. This will make the ratio $\frac{\text{Back E.M.F.}}{\text{Impressed E.M.F.}}$ decidedly greater, and the latter would in its turn make the apparent (total) resistance smaller. As, however, these variations are not proportional, the resultant apparent resistances will follow by no means a "straight line law." Fig. 1 is a curve formed from the series of results, under different currents, which are given in Table I. It will be observed that while current varied from ·83 m.a. to 87 m.a., the apparent total resistance fell from 876 to 88·4 ohms; or, roughly speaking, the current was increased from 1 to 100, and the resistance fell from 100 to 10.

These results form a striking contrast to any before obtained, but an explanation of them may be found in considering under what circumstances previous tests have been made. The Wheatstone Bridge method has hitherto been almost universally used on account of its supposed "accuracy." But it must be asked what was the current in the bath circuit and the E.M.F. across it? A glance at Fig. 1 and Table I. will show the necessity for this knowledge.

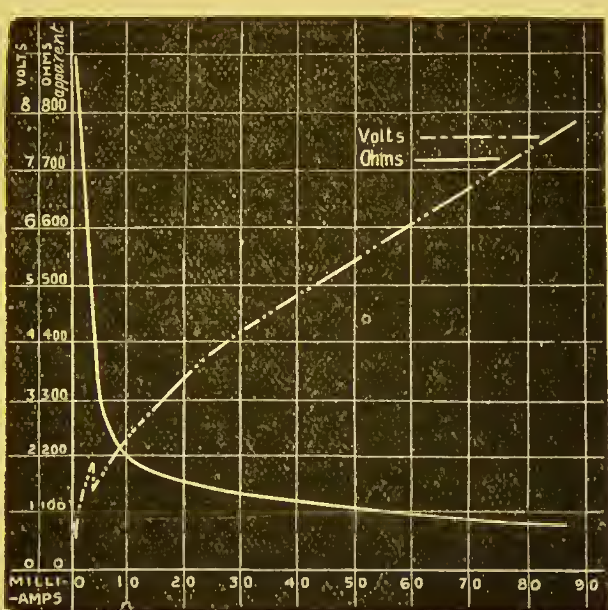

Fig. 1.

In order to settle the question of the suitability of the Bridge for measuring the resistance of the bath, a series of comparative tests were made between the latter method and "volt and ammeter" method, resistance being calculated by the formula $R = \frac{E}{C}$. Throughout all these tests the same measuring instruments were used, and both

voltmeter and milliampèremeter were referred to "standards," and also calibrated by potentiometer

TABLE I.

Resistance of Bath with Different Currents.

Current in M. Amps.	Voltage.	Resistance. Bath and Ammeter.	Resistance. Bath.	Current in M. Amps.	Voltage.	Resistance. Bath and Ammeter.	Resistance. Bath.	Remarks.
		ω	ω			ω	ω	
·83	·74	891	876	16·6	3·0	181	167	Height of water in Bath 17in.; temp. constant at 91 deg. Fahr.
1·75	1·170	668	653	21·8	3·7	149	135	
2·48	1·50	605	590	33·2	4·3	129	115	
3·32	1·75	527	512	43·5	4·87	112	110	
4·15	1·35	325	311	52·2	5·4	103	101	
4·96	1·45	292	278	61·0	6·07	99	97	
5·8	1·62	279	265	69·4	6·69	95	94	
6·62	1·70	256	242	78·3	7·1	90·7	88·7	
7·45	1·76	236	222	87·0	7·9	90·8	88·4	
8·3	1·90	229	215					

method against a Clark's standard cell. Fig. 2 is

FIG. 2.

a diagram of the connections made for this comparative test.

It will be seen that in the "unknown" arm of Bridge there were two parallel branches, one being the voltmeter, having a resistance of 1,100$^{\omega}$, the other consisting of the ammeter (15 ohms. resistance) and the bath. Table II. gives the results of this test, which are certainly remarkable for their closeness.

TABLE II.

Comparison Test of Methods of Measuring Resistance of Bath.

Height of Water.	Wheatstone Bridge. Resistance.			E.M.F.	$R = \frac{E}{C}$ Current in Milliamps.			Resistance.		
	Total.	Bath and Ammeter.	Bath.		Voltmeter Circuit.	Bath and Ammeter.	Total.	Total.	Bath and Ammeter.	Bath.
16in.	105	115	103	1·08	·98	9·32	10·3	105	115	103
15in.	112	123·3	109·7	1·11	1·00	9·0	10·0	111	123·3	108·5
14in.	118	132·03	117·1	1·15	1·01	8·71	9·75	118	132·03	117·1
13in.	124	142·1	124·7	1·18	1·07	8·3	9·37	126	142·1	127
12in.	132	150	135	1·20	1·09	7·97	9·06	132	150	135
11in.	140	159·8	145·4	1·22	1·11	7·63	8·74	140	159·8	145·4

REMARKS.—Bath No. 1, temp. 96 deg. Fahr. Area of Electrodes—Anode,1 47 sq. c.m.; Kathode, 481 sq. c.m.

But the current in the bath circuit at most was only 9·32 m.a., and dropped to 7·63 m.a., not by any means the conditions of practice. The Wheatstone Bridge can, of course, be adapted to measure the bath resistance under working conditions, but it would necessitate the winding of the coils with wire sufficiently large to carry 250 m.a. without appreciably altering its resistance, a high E.M.F.

and adjustable rheostat or cell collector, together with an ammeter of known resistance in the bath circuit. It is an expensive arrangement, requiring considerable skill to manipulate, and at best a roundabout method of obtaining the desired result.

The only conclusion, therefore, to be arrived at is that the Wheatstone Bridge method of measuring the resistance of an electrolytic circuit is misleading, since the "resistance" varies both with the current and impressed E.M.F., the magnitudes of which, under ordinary conditions, are unknown.

A series of tests of the resistances of the bath-water, with and without the body, and at varying heights of water, were next undertaken. The "volt ammeter" method was used, and the current, temperature of water, and position and size of electrodes kept constant throughout. The results are given in Table III. for Bath No. 1, and in Table IV. for Bath No. 2.

TABLE III.

Height of Water.	Water only.		Water & Body.		Resistance.			Remarks.
	E.M.F.	Resistance.	E.M.F.	Resistance.	Displaced Water.	Undisturbed Water.	Body.	
17in.	8·1	91	6·9	77·5	737	103·8	306	Temp. 98 deg. Fahr. Area of Electrodes — Anode, 471 sq. c.m.; Kathode, 481 sq. c.m.; Current, 89 m a.
16in.	8·5	95·5	7·3	82·0	772	110·5	319	
15in.	9·0	101·1	7·8	87·6	817	115·4	364	
14in.	9·5	106·7	8·4	94·5	870	121·6	424	
13in.	10·0	112·4	8·9	100·0	935	127·7	461	
12in.	10·6	119·0	9·6	107·8	1050	134·3	546	
11in.	11·2	126·0	10·2	114·6	1160	140·4	623	
10in.	12·0	134·8	11·0	123·6	1230	151·4	673	

TABLE IV.

Height of Water.	Water only.		Water & Body.		Resistance.			Remarks.
	E.M.F.	Resistance.	E.M.F.	Resistance.	Displaced Water.	Undisturbed Water.	Body.	
14in.	8·2	92·2	7·0	79	745	104·5	324	Temp. 98 deg. Fahr. Area of Electrodes—Anode, 462 sq. c.m.; Kath., 462 sq. c.m.; Current, 89 m.a.
13in.	8·4	94·3	7·3	82	810	106·7	354	
12in.	8·9	100·0	7·8	87·8	930	112·0	406	
11in.	9·9	111·0	8·7	98·0	1130	123·0	482	
10in.	10·9	122·6	9·7	109·0	1400	134·3	578	
9in.	11·9	134·0	10·9	122·6	1860	145	798	

In both cases the subject was immersed to such an extent that the water just covered the shoulders. The difference between the first readings of body resistance in each case is no doubt to be accounted for by the fact that, in order to immerse the body up to the shoulders in the smaller bath (14in. water), the trunk had to be placed at a greater angle from the perpendicular than in the larger bath (17in. water). Fig. 3 will explain this graphically,

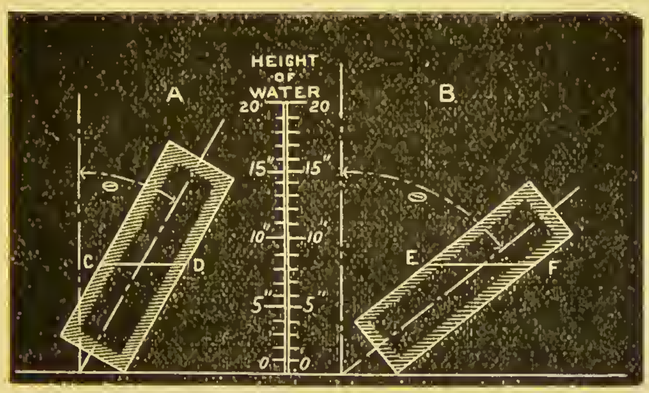

FIG. 3.

Block A representing the trunk of the body in Bath No. 1, and Block B the same in Bath No. 2. C D

and E F are direct lines of current flow, and it will be readily observed that E F is longer than C D. In a uniform conductor the respective resistances of the current paths C D and E F would be in direct proportion to their length; but the fact that the body is a very complex structure will in some measure modify such a law. Nevertheless, it may be safely assumed that there is rise of body resistance when the angle from the perpendicular is increased, although not perhaps in strict proportion with the increase of the length of the current path.

It will be observed that the resistances of the body (when immersed) are considerably lower than any given before. The reason is not far to seek. Primarily, no doubt, the Bridge test has something to answer for; but the deductions, in several instances, have also been in error.

In attempting to unravel this problem it would be best to consider the body and water as parallel branches of a circuit (this will be true if the body occupy the whole length of the bath, but not otherwise). So far as the water is concerned two subdivisions must be considered: that which is displaced by the body, and that which remains undisturbed. These resistances may be placed diagrammatically thus:—

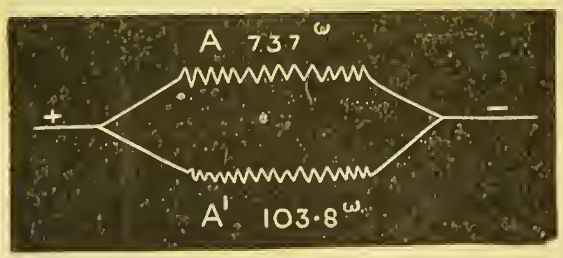

FIG. 4.

A being the resistance of the water which would be displaced by the body; A′ the resistance of the water remaining undisturbed. In this case the resultant resistance will be

$$\frac{737 \times 103{\cdot}8}{737 + 103{\cdot}8} = 91^{\omega} \text{ total resistance of water.}$$

Now place the body in the bath, keeping the water at its original level, and allowing other conditions to remain the same. What has been done is to replace a given volume of water (A 737^{ω}) by the body whose resistance it is desired to measure. By referring to Table III. (water at 17in.) it will be seen that the resultant resistance (water and body) has fallen to 77·5. Diagrammatically the case is

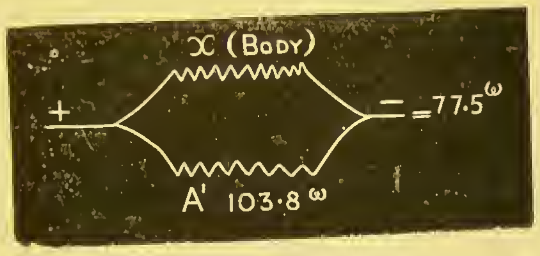

Fig. 5.

and calculating these figures the result will be—

$$\frac{103{\cdot}8 \times 77{\cdot}5}{103{\cdot}8 - 77{\cdot}5} = 306 \text{ resistance of immersed body;}$$

or, reversing the process,

$$\frac{306 \times 103{\cdot}8}{306 + 103{\cdot}8} = 77{\cdot}5 \text{ the resultant resistance of body}$$

and water.

It would appear that this line of argument has not always been followed by those who have investigated the question. Instead of it a plan somewhat similar to the following seems to have been adopted. The resistances of bath (with and without body) being

first measured, the results were calculated by the formula —

$$\frac{\text{R of water} \times \text{R of water and body}}{\text{R of water} - \text{R of water and body}} = \text{R of body.}$$

At least, taking the values of resistance as given, the above formula will produce the same results. Now applying this formula to the resistances here given there is obtained $\frac{91 \times 77{\cdot}5}{91 - 77{\cdot}5} = 522^{\omega}$ as the resistance of the body. In this case the water was at the same height (17in.) with and without the body; therefore what was done amounted to taking away one parallel branch of the water circuit and replacing it by the body. But what is the value of the figure 522^{ω}—what is its meaning? Diagrammatically the first state of affairs was that represented in Fig. 4, *i.e.*, when measuring resistance of water only. With the body immersed the position was as in Fig. 5. But in the resultants (91^{ω} and $77{\cdot}5^{\omega}$) only one constant factor was present; that is to say, the resistance of the undisturbed water ($103{\cdot}8^{\omega}$). In short, the figure 522^{ω} is nothing more nor less than the resistance which, if placed as a parallel branch to 91^{ω}, would give a resultant of $77{\cdot}5^{\omega}$, the position of affairs being—

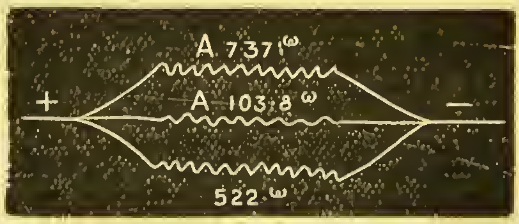

FIG. 6.

or $\frac{737 \times 103{\cdot}8}{737 + 103{\cdot}8} = 91$, and $\frac{91 \times 522}{91 + 522} = 77{\cdot}5^{\omega}$

In our case the branch A (737) was *replaced* by the body, therefore the resistance, which if placed as a parallel to A ($103{\cdot}8^{\omega}$) gives a resultant of $77{\cdot}5^{\omega}$, must be less than 522^{ω}.

Now assuming that the same volume of water was in the bath before and after the immersion of the body, how would the case stand? On immersing the body, a certain amount of water is displaced, increasing the sectional area of the composite conductor as against that of the original water. Is the resistance of the *water* the same before as it is after immersing the body? Admitting that it is not the same, would it be correct to add water to the original amount to bring it to the level to which it rose on immersing the body, and, having measured its resistance, calculate therefrom the resistance of the water displaced by the body? No. Consider an analogous case. Assume that there is a water vessel ($4'$ high $\times$ $3'$ wide $\times$ $6'$ long) and a block of conducting material ($1' \times 1' \times 3'$) which it is wished to immerse. Take the specific resistance of water to be 10^{ω} per foot cube, and that of the block at 5^{ω} per foot cube; the water being $3'\ 0''$ high before immersion.

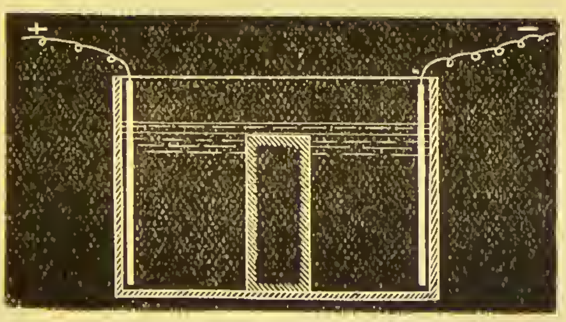

FIG. 7.

In the first case place the block vertically (as in Fig. 7), and there will be obtained —

Resistance of Water.		Resistance of water required to be added to raise from low to high level.	Resistance of Displaced Water.	Resistance of Block.	Total Composite Resistance (as in Fig. 7).
Before immersion.	After immersion.				
$6{\cdot}96^{\omega}$	$6{\cdot}78^{\omega}$	118^{ω}	$3{\cdot}33^{\omega}$	$1{\cdot}66^{\omega}$	$6{\cdot}04^{\omega}$

Comparison of columns 3 and 4 will show the fallacy of the "added-water" theory. Now lay the block horizontally as in Fig. 8

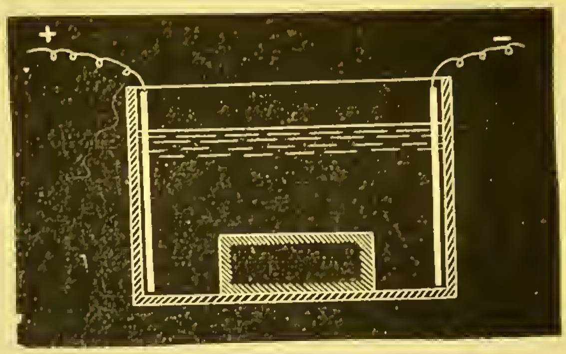

FIG. 8.

and the resistance will be —

Resistance of Water.		Resistance of water required to be added to raise from low to high level.	Resistance of Displaced Water.	Resistance of Block.	Total Composite Resistance (as in Fig. 8).
Before immersion.	After immersion.				
$6{\cdot}66^{\omega}$	$6{\cdot}68^{\omega}$	118^{ω}	30^{ω}	15^{ω}	$6{\cdot}00^{\omega}$

the proportion of total current taken by block coming out as

Fig. 7.	Fig. 8.
44·5 per cent.	17·7 per cent.

It must be admitted that this analogy cannot be strictly applied to the bath under the usual working conditions, since, in both Figs. 7 and 8, a large proportion of the water remains in "series" with the block; whereas with the patient very little (if any) of the water is so left in practice. Nevertheless, it is a convincing proof (1) that the resistance of a given volume of water alters upon immersing a foreign body, by reason of the difference of shape. (2) That the measurement of resistance of the "added" water is not a true index of the resistance of the displaced water. (3) That both the resistance of displaced water and body (and, therefore, the current ratio) will vary, not only with the volume displaced, but also as to the position occupied relatively to that of the other water circuit, and also as to the respective conductivities.

Reverting again to Tables III. and IV. it will be seen that the body and displaced water resistances are approximately as ·5 to 1; or, reciprocally, their conductivities are as 2 to 1. Taking now the first reading of Table III. (body resistance 306^{ω}, undisturbed water $103 \cdot 8^{\omega}$), the relative conductivities and consequently the relative currents are as 34 is to 100; or in other words, the body under these conditions took 25·3 per cent. of the total bath current. Below are given the proportions of total current taken by the body at varying heights of water in both baths calculated from Tables III. and IV.

TABLE V.

Height of Water.	Proportion of Total Current passing through Body.	Remarks.
17in.	25·3 per cent.	Bath No. 1. Current 89. m.a. Temp. 98° Fahr. Area of Electrodes:—Anode, 471 sq. c.m. Kathode, 481 sq. c.m.
16in.	25·8 ,,	
15in.	24·09 ,,	
14in.	22·30 ,,	
13in.	21·7 ,,	
12in.	19·7 ,,	
11in.	18·3 ,,	
10in.	18·5 ,,	

TABLE VI.

Height of Water.	Proportion of Total Current passing through Body.	Remarks.
14in.	24·4 per cent.	Bath No. 2. Current 89 m.a. Temp. 98° Fahr. Area of Electrodes :—Anode, 462 sq. c.m. Kathode, 462 sq. c.m.
13in.	23·2 ,,	
12in.	21·6 ,,	
11in.	20·4 ,,	
10in.	18 8 ,,	
9in.	15·4 ,,	

From these Tables it appears that the body receives under the usual working conditions when fully immersed about 25 per cent. of the total current. But it must not be forgotten that this 25 per cent. represents simply the *average* current passing through the body, and by no means represents the *maximum*. In any given cross section of a conductor formed of two substances, having different specific resistances and placed in parallel with one another, the proportion of the total current taken by each branch will vary directly, as

their respective sectional areas, and inversely as their respective resistances. Now, the average specific resistance of the body is only half that of the water; it therefore follows that if the trunk of the body occupy one half of cross section of the bath (taken, of course, at right angles to the direction of current flow), the current through that portion of the body will be 66·6 per cent. of the whole. Again, take a cross section of the bath at the position of the ankles. That portion of the body may occupy only $\frac{1}{50}$ part of the sectional area; the current flowing in that part would, under those circumstances, be about 4 per cent. of the total. Reference to Figs. 3, 7, and 8 will further elucidate this point. But it must by no means be assumed that the resistance of the immersed body is uniform; although the results given in Tables III. and IV. appear to show that the resistance of the trunk is practically so.

Therefore, to sum up the case, the proportion of the total current taken by the body will vary with the temperature of water (*i.e.*, its specific resistance), the total volume of water, the volume and resistance of displaced water, the specific resistance of the immersed body, and the position which the latter occupies relatively to that of the water circuit. However, under the usual working conditions, it will be safe to say that the average current passing through the body is about 25 per cent. of the total, and that the maximum is probably nearer 50 per cent., *i.e.*, through the trunk.

Certain skin reddening and tingling sensations

out of proportion to what was supposed to be the amount of current passing through the body in the bath, have been previously noticed, and the suggestion has been put forward that these might be due to the impinging of certain current lines upon the body, the said current afterwards passing round the body. It now appears that these results find their true explanation in the large current passing *through* the body. The smooth and painless action of such a current cannot but be wondered at, and is only to be accounted for (1) by the very large skin surface exposed to the current, and (2) to the effect upon the skin of immersion in hot water.

One point in the construction of the bath should not be overlooked, viz., that *fixed* electrodes, a large proportion of which are "idle" during treatment, are not desirable. No doubt it is very convenient to be able to switch from one set of electrodes to another, but when the effect which the presence of these metal electrodes has upon the distribution of the current in the bath is considered, it becomes necessary to sacrifice convenience to the cause of electricity. For instance consider a cross section of the bath at the position occupied by the trunk, and assume the resistances of the body and water at that place to be each 50^{ω} (of course, they are in parallel); now place also in parallel with them an "idle" metal electrode having a resistance of 1^{ω} It will be readily seen that the body and water are, to all intents and purposes, short-circuited, and that practically the whole of the current passes viâ the "idle" electrodes. Unless, therefore, it is purposely

intended to shunt the current past a certain portion of the body, no other electrodes than those actually in use should be allowed to remain in the bath.

Indeed it is advisable as a rule to beware of divided anodes and divided cathodes, *i.e.*, the so-called "multipolar" bath. Such an arrangement introduces many electrical complications; as an instance suppose a case in which there is one cathode plate and two anodes; of the latter the one which is the nearer to the cathode although positive to the cathode must be negative to the other anode. It is like the "neutral" in a three-wire electric lighting system.

Another point bearing on the construction of the bath may be shortly noticed here. It has been proposed by Gärtner to insert a partition or "diaphragm" (through which the body of the patient passes) across the bath. Now supposing that the junction of the body with this partition approach the condition of a "water-tight joint," it is evident that practically the whole of the current passing through the bath must pass through that part of the patient's body which is in contact with the partition, no other route being open. But it is through this particular part of the body *only* that the entire current will pass. Is such a result desirable? It is obvious that an arrangement of this kind represents either a disastrous concentration of current on one particular part or an inadequate current for the rest of the body.

Dealing next with the interesting phenomenon of

"polarisation": it is evident that this is responsible for many of the miscalculations already described, inasmuch as it is owing to polarisation that the apparent resistance of the bath alters with E.M.F. and current. It has been objected that the "back" E.M.F. is not a true resistance, and that it should, therefore, be deducted from the impressed E.M.F. and that calculations be based solely upon the ohmic resistance. But it must not be forgotten that the "ohmic" resistance itself alters as a result of polarisation, by the formation of gaseous envelopes round the electrodes. In practice, moreover, it is impossible to eliminate polarisation and its resultant effects. These cannot be got rid of, and the inevitable must be accepted. Therefore resistance must be treated as the "algebraic sum of all the forces opposing the current."

It has been stated that in measuring the resistance of the body it is desirable to do so by means of an alternating current and telephone, inasmuch as by this means the difficulty of polarisation is eliminated. If, by this, it is to be understood that polarisation does not exist with an alternating current, such a statement cannot be accepted. Admitting that at the end of every complete period of an equally alternating current, the amount of decomposition is nil; yet, during each half period of the cycle, electrolytic action is taking place, only, however, to be reversed in the succeeding half period. When the current is not equally alternating (such a current as is given by an induction coil), there is a resultant electrolytic action at the end of each

period, in proportion to the difference between the two half periods, giving rise to a gaseous envelope and consequent increase of the ohmic resistance. Still further, under certain circumstances, electrolytic action has been known to cause a lag of phase in an alternating current,* thus proving conclusively the existence of a counter electromotive force.

A test of the amount of discharge current obtainable from the bath after charging with continuous current was made, and the curve Fig. 9 is formed from these results. The charge was begun with 20 m.a. and then increased by 20 m.a. at the end of each two minutes until 100 m.a. had been passing for two minutes, and then suddenly reversed through an ammeter (R = 15$^\omega$) and readings taken at intervals of one minute. The discharge current was 1·5 m.a. at the moment of reversing, and fell to ·66 m.a. at the end of 17 minutes. The height of water was 14in., temp. 98° Fahr.; area of electrodes: Anode, 462 sq. c.m.; Kathode, 462 sq. c.m.

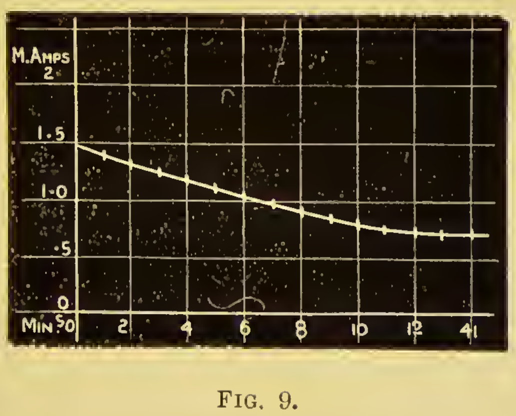

Fig. 9.

* "Alternate Current Electrolysis," by W. R. Cooper, M.A. "Electrician," Vol. xxxv., p. 842.

The following is a dimensional sketch of Bath No. 1 :—

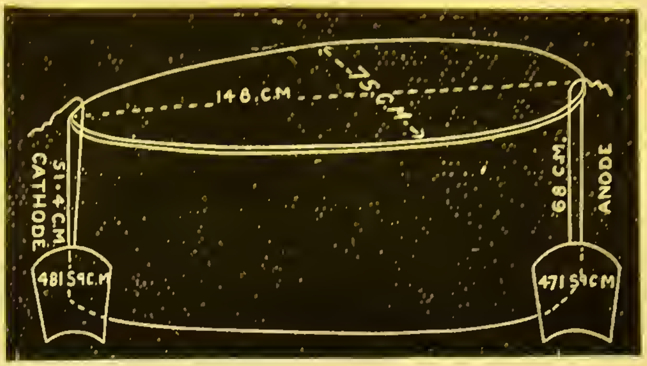

Fig. 10.

The corresponding dimensions of Bath No. 2 are as follows :—

Length, 140 c.m.
Width at widest part, 71 c.m.
Height at top, 54 c.m.
,, at bottom, 38 c.m.
Area of electrodes { Anode, 462 sq. c.m.
Cathode, ,, ,,

(Sides and ends in both baths are perpendicular.)

CHAPTER II.

THE THERAPEUTICS OF THE HYDRO-ELECTRIC BATH.

Definition of Terms.—It is well in the first instance to come to an understanding about terms. The electric bath is correctly and conveniently spoken of as "monopolar" or "dipolar." It does not seem necessary to admit the word "multipolar," of recent introduction. To regard the multiplication of electrodes as a divided anode or a divided cathode is probably more simple and certainly more correct. The monopolar is that form of bath in which one electrode only is in the water; the other is applied to some portion of the patient's body (neck, arm, hand) out of the water; and this will be the point of entrance or emergence of the current, *i.e.*, it will be the anode or cathode, according to circumstances. The opposite pole is the whole of the patient's body in contact with the electrised water; or, in other words, the water in contact with the body constitutes one huge electrode, adapting itself accurately to every irregularity of surface and carrying a very widely diffused current. The advantage of this method of application is that the amount of current entering the

patient's body is accurately known. Its disadvantage is, that it involves a great concentration of the current on one spot. The latter is an effect that the electric bath is specially designed to avoid, except in a modified way, to be hereafter detailed, which is carried out by to some extent concentrating and directing the lines of current-flow through the water.

In the dipolar bath both electrodes are in the water; that is, the current is led off from both poles of the battery or coil or current controller direct to the water, the current being thus applied to the patient's body only through the medium of the water. For most purposes of general electrisation this is the form usually preferred. Its painless and widely-distributed current offers certain unique advantages which, in some cases, make it an admirable method of treatment, and an almost indispensable weapon in the equipment of the electrical physician. It is "wasteful of current," but with sufficient electrical power available, and knowledge and apparatus to efficiently control it, such a consideration has no importance.

It is obvious that in the monopolar bath the whole of the current must enter the patient's body. In the dipolar form the conditions are much more complex; and it has been shown by the foregoing experimental results that the proportion of current the body receives is by no means easy to arrive at.

The various kinds of bath must be further designated by the source of electrical supply or more

properly by the physical nature of the current used. Thus either the monopolar or dipolar bath will be "continuous," or "alternating." I. If continuous it will either be (*a*) "uniform," *i.e.*, a current produced by a uniform electro-motive force, such as is that of a Leclanché cell ("galvanic"), or by the practically straight line of electro-motive force of some central station lighting currents; or it will be (*b*) "pulsatory," *i.e.*, a current continuous and always flowing in one direction, but not absolutely uniform in strength. The current produced by a single constant current dynamo having few sections is of this order (Fig. 11). II. If alternating it may be (*a*) "dissymmetrical," *i.e.*, a current produced by an electro-motive force of which the positive and negative maxima are neither equal nor smoothly attained; and the most familiar example of this is the current produced by the ordinary medical induc-

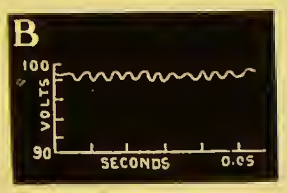

Fig. 11.*

Fig. 12.*

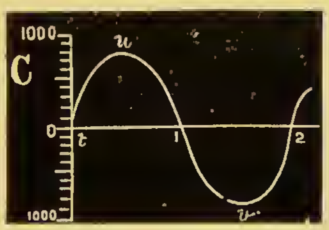

Fig. 13.*

tion coil "faradaic" (Fig. 12); or the current may be (*b*) "sinusoidal," *i.e.*, a current produced by an

* After Houston and Kennelly.

electro-motive force which gradually attains its positive and negative maximum, shows no lost time and no actual interruptions (Fig. 13). It is a current, in short, whose electro-motive force is represented graphically by a "curve of sines." A current of this order is furnished by the therapeutic alternator and is very closely approximated by some alternating light circuits. The use of the latter is fast growing in favour, and, as will be subsequently shown, has been attended by excellent therapeutic results.

The above designations appear in the following scheme :—

Hydro-Electric Bath.	B. Dipolar.	I. Continnous	(*a*) Uniform (galvanic, modern central lighting stations). (*b*) Pulsatory (a single constant C. dynamo of few sections).
	A. Monopolar.	II. Alternating.	(*a*) Dissymmetrical (faradaic). (*b*) Sinusoidal (some therapentic alternators and the more or less sinusoidal currents of alternating light circuits).

A special section will be devoted to each of the above varieties of bath, and their therapeutic effects will be then discussed.

Individual Susceptibility —Individual susceptibility to the action of electrical currents varies within an astonishingly wide range, and here, therefore, not less, and perhaps more than in other departments of therapeutics, the physician must often be content to feel his way in the light of a cautious experimentation. In the case of the electric bath there arises the additional complication that in order to decide the amount of current to be used it becomes

necessary in the first instance to form an estimate of what proportion of total current running through the bath will fall to the share of the patient. The chapter on physics has already dealt with this intricate and important problem.

The arrangements for the proper administration of an electric bath depend on the special indications in each individual case, and necessarily also to some extent on the individual views of the physician. But there are certain broad rules of general application which may not be neglected, and the first of these is this, that it is often on attention to a number of small details that the efficacy of this form of electrisation will very much depend.

Temperature of Bath.—The temperature at which the bath is administered will depend upon the nature of the case, the susceptibility of the patient, and to some extent on the weather, but generally the proper degree will be found between 90 and 98 F. (32-37 Centigrade). It is necessary not to lose sight of the electrical fact that the hotter the water the greater its electrical conductivity, and therefore the greater share of current it appropriates at the expense of the patient's body. For similar reasons, viz., that the conducting power of the water becomes thereby increased, it is unsound in theory and generally objectionable in practice to add acid or salt to the water of the bath. If, however, there are any special reasons why these or similar substances be added, or that the temperature of the water be raised, it is really of little consequence from an electrical point of view, and only neces-

sitates the employment of a stronger current in proportion to the increase in temperature.

Precautions.—The ordinary rule of not taking a bath after a full meal ought to be followed. In the case of insane, anæsthetic, paralysed, or other helpless people special precautions will be used. In the case of certain heavy patients, paralysed in the lower limbs only, the writer has availed himself of the suspension tripod ordinarily used for locomotor ataxy. With this placed across one upper corner of a low bed, and with an improvised seat or " chair " made of straps or stout webbing, he has easily with the aid of two nurses swung such a patient into a bath placed alongside the bed. If wholly helpless the apparatus figured and described by Mr. Stephen for the cold bath treatment of typhoid may be used.* In

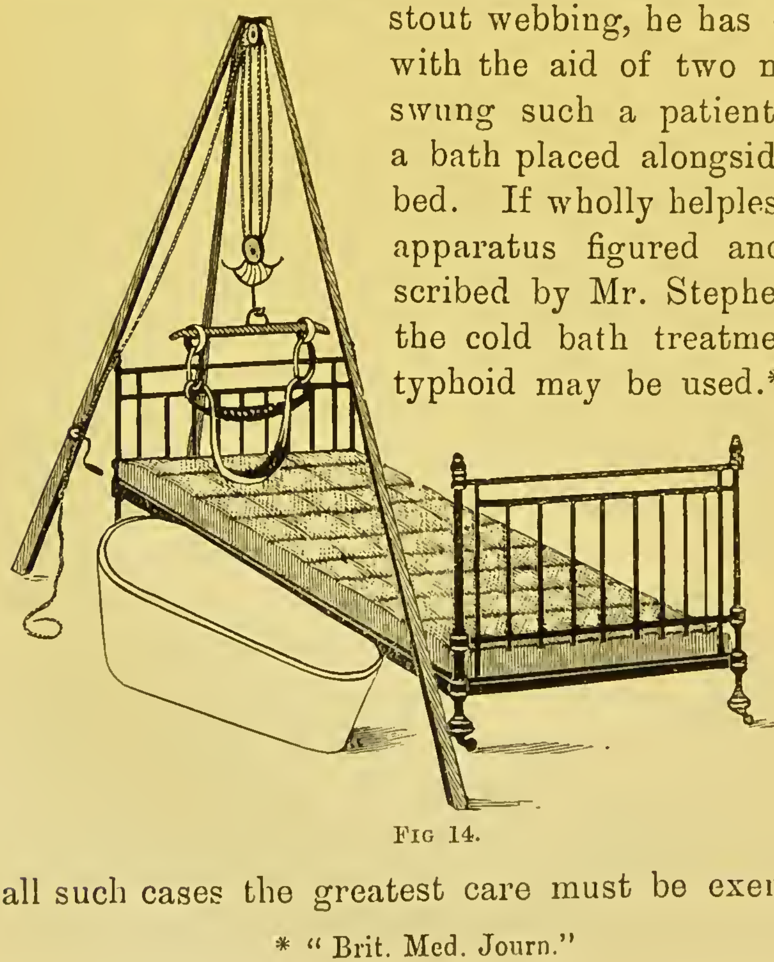

Fig 14.

all such cases the greatest care must be exercised

* " Brit. Med. Journ."

not only in placing the patient in the bath, but in looking for wounds, ulcerated surfaces, skin abrasions, and protecting them by a piece of sticking plaster

FIG 15.

or other means from the action of the current. It is important also before placing the patient in the bath to inquire into the condition of the "sensibilities," — the tactile, pain, temperature sense. It is within the writer's knowledge that in the case of tabetics who were also anæsthetic serious ill effects have followed the administration of electric baths by incompetent persons whose only limit of current

strength seemed to be the limit of the patient's endurance.

Position of the Patient in the Bath.—The amount of current that any special part of the body will receive must depend upon its position in the bath. This will be decided according to circumstances; completely immersed if it be desired to act on the whole length of the spine, or sitting upright on the "gluteal" electrode if only the lower part of the back is to be influenced; or placed in the direct line of current between the two lateral electrodes in cases where it may be intended to act chiefly on the hips or on the organs of the abdomen or pelvis. In the latter position the arms may be allowed to lie across the line of current flow, or carried to the front of the patient so as to avoid it. The quantity of current that the body, or any special part of it, receives has been already shown in the preceding chapter; but it is evident that the amount will vary according to the proximity of the body to an electrode; therefore, by altering the position or number of electrodes, the current strength falling upon any special part may be correspondingly altered, that is, the current may be "localised" for any special indication, as for example, a spinal affection, a sciatica, or disease of any special articulation. The electric bath is thus seen to be a method of general electrisation with a certain power of localisation.

Current Density.—The question of "density," which is so important a factor in "dosage," and which, in ordinary electrical applications, depends upon the size of the electrodes, becomes a very com-

plicated one in the dipolar bath. Here it is evident that not only the size of the electrodes is to be considered, but also the amount of diffusion the C. undergoes in passing through the water from the electrode to the body; and this will depend partly on the size of the electrode, partly on distance, and partly on the conductivity of the water. In other words, there is to be considered not only the size and position of the electrodes electrising the water, but the whole extent of water in contact with the body has to be regarded as a huge electrode adapting itself to every irregularity of the body, carrying a widely diffused current, with a density diminished in proportion to its diffusion. In all electro-therapeutic work it is absolutely essential to aim at clear ideas about density. If the size of the transverse section of the circuit varies, the electricity must be of the greater "density" at the narrower parts. This fact is generally stated by saying that with a given current the density is inversely proportional to the transverse section of the conductor or $D = \frac{C}{S}$. The current is "comparable to a girl's hair, which may be gathered up into a narrow tress or allowed to flow loosely, without changing the number of its constituent parts."

Regulation of Current Strength.—The patient having entered the bath and his position being duly arranged, the current will be turned on and very gradually brought to the strength required. But if the operator have any doubt as to the accuracy and smoothness in working of his current

regulator, it will be found a useful precaution to let the patient sit towards the middle of the bath with his back some distance from the upper electrode and his feet drawn up from the bottom one, and from this position gradually to extend himself after the current is made.

Direction of Current Flow.—The question of polarity will have to be decided on general principles, or more probably by a careful trial. The late Dr. Steavenson states that the direction of current flow should "generally be from the feet to the head." No reason seems to be assigned for this rule, and it is not quite easy to feel satisfied of its usefulness. At the same time it is necessary always to bear it in mind as being the opinion of a high authority and the outcome of a large experience. The necessity for a very gradual making and breaking of the circuit, unless when the special effects of sudden rupture or reversal are desired, are amongst the things common to ordinary electrical applications, and need not be insisted on here. If a continuous current be running the galvanometer and the patient must both be carefully watched. If an alternating current be in use, and no measuring instrument in circuit, the operator will not only regulate strength by the arrangements of his coil, or transformer, or by his rheostat, but will also from time to time estimate its strength by his hands extended in the water to the extreme ends of the bath.

Duration.—The period of immersion will usually be 15 to 20 minutes, and will only on rare occa-

sions exceed or even extend to half-an-hour. The first bath of a series ought to be more or less an experimental one, and of even shorter duration than the first-named time. As the patient emerges from the bath, and stands up in the water, a cold affusion in some form or a mild Faradaic douche may be administered, according to individual toleration. The patient who finds it necessary to undergo a course of electric baths has not generally any considerable resisting power to cold. He is moreover often nervous and hypersensitive. Therefore if stimulation either by the cold affusion or by the electrised douche be attempted, it is imperative that the operator have his apparatus well in hand, that in other words he must be able easily and accurately to regulate both its electric and its hydriatic strength. The light bathing dress is now removed, and after vigorous friction the clothes are resumed and a quarter of an hour's rest is taken. Then, weather and strength permitting, the patient walks part at least of the distance home.

Construction and Dimensions of the Bath.—The substance of which the bath itself is made must clearly not be of metal, for the reason that however carefully covered the metal may be, the current is sure to get at it somehow, sooner or later, and run round it in preference to entering the water. It is best made of oak or porcelain, perhaps porcelain for choice, if expense need not be considered. Insulation must be carefully attended to, both of conducting wires and waste pipe, the latter being insulated from earth by a short length of rubber tubing let in

near the bath. Or better by having the discharging orifice of the bath "overshot" above a shallow tank or sink beneath it, the sink having no connection with the bath, but having the waste pipe attached to it. With coil currents having perhaps an electromotive force of several hundred volts, it is evident that insulation is a very important matter.

The bath is an ovoid oak tub, 148 c.m. long and 75 c.m. at greatest width, which is about 5 c.m. nearer the head than the foot. Height at head, 68 c.m.; height at foot, 51 c.m. In one form of bath there are five electrodes, fixed to the sides of the bath, the latter being pierced for the passage of the conducting wires. These electrodes are of bright metal covered only by light removable open wooden framework, size as follows :—

"Cervical"...	28 × 29 c.m.
"Lumbar"...	24 × 17 c.m.
"Lateral" (2)	26·5 × 18 c.m.
"Gluteal" (circular) ...	30 c.m. (diameter).
"Terminal" (foot)... ...	22 × 38 c.m.

In addition to these there is an electrode for monopolar purposes, consisting of a removable metal rod, one inch in diameter, covered with wash leather. This is fixed across the widest part of the bath, and can be conveniently grasped by the hands. These electrodes are connected, by carefully insulated wires, with seven terminals, and the latter in turn lead to a switch-board, so arranged that by the insertion of plugs any electrode or combination of electrodes can be brought into action, either as anode or cathode. The connection with

the battery, coil, or other source of supply, is by means of well-insulated connections leading to two ordinary "binding posts" on the "commutator." This arrangement with fixed electrodes is convenient, but it has certain obvious disadvantages which render it undesirable. (1). The piercing of the sides of the bath is certain sooner or later to lead to leakage. (2). When a current is passing there are certain electrical complications, as explained in the preceding chapter, that may arise from the presence of the electrodes even when the latter are not in action. It seems better, therefore, to have the electrodes connected as above with the switch-board by means of stoutly insulated wire, which does not, however, pass through the substance of the bath, but dips into the water, and is stiff enough to hold the electrode in position. By this arrangement the electrodes are removable. Their number, size, and shape will depend upon the theoretical considerations already advanced, looked at in the light of the experimental results set forth in the chapter on Physics. The writer advocates the use of a "cervical" and "lumbar" electrode, the dimensions of each being about 25 × 15 c.m. These can be used separately or together. At the foot of the bath there will be a "terminal," or foot electrode of slightly larger dimensions than the cervical or lumbar. The two last named can be used as right and left "lateral," and one of them covered by a light wooden framework may at other times be utilised as a "gluteal" electrode upon which the patient sits. The only further addition,

a very useful and even necessary one, is the so-called "paddle" electrode. By means of a long insulated handle such an electrode can be applied to the vicinity of any part of the body on which it may be desirable to concentrate the current. Suitable dimensions for this electrode will be 12 × 18 c.m. For monopolar purposes the metal rod above described is useful. It is best in the interests of cleanliness, if for no other reason, that the electrodes be of bare bright metal, as the cleansing and changing of covers is often very imperfectly attended to, a matter sometimes of serious consequence, as several unfortunate instances show.

Electrical Equipment.—For carrying out treatment by these methods the electrical equipment must be not less complete than that for other purposes. The diversity of the effects required, and the magnitude of the currents that may have to be employed, point to the necessity of having the supply under safe, easy, and complete control. Apparatus will be discussed in special sections, but speaking generally the requirements will be :—1. A continuous current supply in the shape of a battery with low resistance, which will work up to a powerful current strength, say, 300 m.a. through the estimated resistance. If supply be taken from an electric light circuit, it will have to be safeguarded by a "reducer of potential." 2. A means of opening and closing the circuit and of regulating strength by easy gradation so as to avoid pain or shock, *i.e.*, a cell collector or a rheostat. In dynamo circuits this is safely and easily effected by the traversing

interlocked shunt rheostat, or in alternating circuits by a suitable transformer. 3. A milliampère meter, *i.e.*, a galvanometer graduated in milliampères, and registering up to, say, 300. 4. A powerful induction coil for faradaic bath or supply from a therapeutic alternator or from alternating electric light mains. 5. Some means of suddenly reversing the current ("current reverser" or "pole changer"), as well as an arrangement for throwing the two forms of current together for combined use ("current combiner" or "De Watteville key"). These are occasionally useful, but are not indispensable. 6. As an adjunct, but not an actual necessity, may be mentioned a voltmeter, useful for occasionally determining the electro-motive force of the battery or of any particular cell, as well as for other purposes. Some galvanometers become voltmeters by suitable adjustment.

Thermal Effects.—Before proceeding to the consideration of special forms of bath it is well, in the first instance, to clear the ground by distinguishing between the electrical and the purely thermal effects of any bath. The warm bath, *i.e.*, the bath at 95 to 104° F., slightly increases the activity of the circulation, and somewhat retards tissue metamorphosis. It is a valuable soothing agent, but in other respects its effects on the system are almost inappreciable (Shelley). It appears, therefore, that there is not much to be expected from the water bath *per se* at the temperatures recommended. But as a means of applying electricity to the body water at such a temperature is invaluable.

Physiological Effects.—The physiological effects of the electric bath are thus summed up by Erb:—"Respiration diminished by di-polar, temperature slightly lowered by mono-polar, metabolism promoted considerably by di-polar, slightly by mono-polar, and secretion of urine increased. Appetite and digestion are improved, the genital functions are stimulated, circulation and nutrition are benefited, sleep notably restored, and new vigour imparted to the mental and physical faculties. In short, the electric, and especially the faradaic, bath is credited by all with a powerful invigorating and refreshing action upon the human frame." All who are conversant with the subject will recognise the accuracy of this general statement, but it is scarcely necessary to say that a good deal has been learned about the electric bath since this was written.

Therapeutic Effects.—Speaking broadly, the painless and evenly distributed current of the general electric bath makes it one of the best methods of electrisation, with, at the same time, a considerable power of concentration on special parts according to the indications of the case. In all states of general debility and impaired nutrition (Erb), in weakness or exhaustion of the spinal nervous system, "nervous dyspepsia," palpitation, hysteria (Erb), neurasthenia, "nervous breakdown," and many of those diseases referable to some derangement of the nervous system without appreciable lesion, commonly called neuroses, it may be resorted to with excellent and unique results. Neuralgias, sciatica (whether perineuritic or purely neuralgic), paralyses

both of central and of peripheral origin, chorea, primary lateral sclerosis, muscular rheumatism, gout, rheumatoid arthritis, and occasionally chronic articular rheumatism, are all recorded to have been cured or alleviated by its use. It has been used with good effect in some irritative conditions of the spinal cord, in alcoholic or mercurial tremors, plumbism, and even in paralysis agitans (Lehr, Erb), and in peripheral neuritis, from whatever cause, though not, perhaps, in every stage. There may also be enumerated the excellent results (of the faradaic bath) recently recorded by Segretti in the treatment of rickets. In connection with the alternating dynamo current bath very special attention must be drawn to the still more recently recorded experiences of Gautier and Larat, not only in many of the above conditions, including rickets, but also in "lymphatisme" obesity, eczema, and many so-called diatheses and diseases due to failure or perversion of nutrition.

CHAPTER III.

THE CONTINUOUS CURRENT BATH.

For the continuous current bath (" galvanic ") there will be required a battery which should consist of 20 large (three-pint or two-quart) Leclanché cells. The larger the cell the greater its electrical capacity, and the longer it will last before requiring renewal; and the simpler in type the easier to recharge, and the less liable to get out of order. If the current from such a battery be controlled by a rheostat it is necessary to be quite sure that the latter is made of some material that will stand a current of 250 or 300 milliampères.* A double-cell collector taking up one (certainly not more than two) cells at a time will, perhaps, be found more generally useful than a rheostat. Having decided upon the amount of current likely to be required, the necessary strength of the battery will be arrived at by a calculation of the following kind:—Maximum current required for the bath (say), 300 m.a.; total resistance of circuit, about 90$^{\omega}$ (R. of bath with body 77·5$^{\omega}$; R. of one Leclanché cell ·5; R. of galvanometer with 100 shunt, 2); E.M.F. of one

* A circular carbon rheostat with a glass dial and a mercury contact is often sold. This is a useful instrument, but not suitable for bath purposes, inasmuch as it heats seriously with a current of 100 m.a.

Leclanché cell 1·5, therefore $\frac{30}{90} = 330$ m.a. In other words, a battery of 20 Leclanché cells, representing an E.M.F. of 30 volts, will give a current of 330 m.a. through, the estimated resistance.

With the di-polar form of bath and a bath-tub of the dimensions indicated, the writer finds that the depth of water being 17 inches (with the patient immersed), and with the cervical, dorsal, and terminal electrode in action, he usually employs a current strength of 50 to 200 milliampères. In the first bath the current is very gradually raised to the lower figure, and allowed to remain there for the first five minutes. A somewhat greater strength is gradually attained during the rest of the time, which altogether extends to eight or ten minutes for the first bath. Duration, direction, and current strength will vary according to the therapeutic results aimed at, the susceptibility of the patient, the number of electrodes in action, and other circumstances. The case is then watched for a day or two, and another bath given with an increasing current. Tolerance having thus been obtained, and no contra-indication having appeared, the rest of the course (a course is eight to twelve baths) will be administered on successive or alternate days, according to circumstances and the nature of the case.

The alternating current, especially in the more or less sinusoidal form of the alternating light circuit, seems for the moment to be everywhere in the ascendant. It is difficult, therefore, at the present moment to assign to the continuous current bath

the exact place it will ultimately hold in electro-therapeutics. Much is expected from it in the treatment of rheumatoid arthritis, and it is in this class of cases, perhaps, that it is most frequently resorted to. It would seem to fulfil the double indication of combining central with peripheral treatment. The writer is seldom fortunate enough to encounter these cases in their early stage, where they can be dealt with as trophoneuroses without serious local mischief; but even when of some standing and with articular manifestations well developed, he has sometimes seen locomotion improved and pain relieved. His experiences of this bath in other diseases may be summarised thus:—In muscular rheumatism frequent and rapid cures; not superior, however, to other electrical methods. In chronic articular rheumatism results on the whole disappointing. Gout often improved after a course of baths in suitable cases, but being generally combined with other remedies, and always with dieting, the exact relationship of cause and effect becomes comparatively obscure. Sciatica,—good results, not superior to alternating C. baths, and not, perhaps, superior in the majority of cases to other electrical methods. "Urethral synovitis" yields to these baths only when the disease has continued for some time, and is probably waning in the ordinary course of events. Locomotor ataxy,—occasional alleviation in symptoms, but the improvement not sufficiently constant to distinguish it from those periods of arrest which often characterise the disease; not all such cases are suitable.

Ordinary cases of chorea sometimes get rapidly well under this treatment, as they do after faradaic baths, or any other form of treatment, or after no treatment at all. But that comparatively small class of cases known as "relapsing" chorea has been treated with only temporary benefit, lasting, perhaps, for only a few hours after each immersion; seldom with a permanent success. In amenorrhœa a constant current localised between the lateral and gluteal electrodes has in several instances been found quickly successful. But it is by no means to be assumed that because the tendency of these baths is sometimes to increase menstruation that therefore the same procedure may always be expected to induce that function when in abeyance. Amongst the rarer cases one of melancholia and one of hysterical paralysis have been improved. In a very considerable number of cases of neurasthenia this form of bath has been found useful, especially as a beginning of treatment, but it is usually necessary to add also direct electrisation of the head. A case of "ataxic paraplegia" has been notably benefited, and in Parkinson's disease the tremor has been temporarily alleviated. In the four last-mentioned cases alternating currents were also used. The following selected case, occurring in the practice of the writer, illustrates the use of the constant current bath as an aid in the treatment of a typical neurasthenic.

A physician, 46 years of age, of a neurotic family, strictly temperate habits, in active professional work, and living in an atmosphere of considerable social excitement, suddenly broke

down about seven months ago. His first and greatest trouble was insomnia. Obliged to give up work he underwent, during three or four months, a variety of medication, and was eventually sent to me by his medical man for the electrical treatment of the insomnia. I saw him for the first time early in February. He was not emaciated, pallid or bloodless. With most of the external appearances of good health, he was yet the picture of a neurasthenic—and, it may be added, the embodiment of self-concentration. His mind never for a moment strayed from himself and his ailments. In every line of his story and in every lineament of his face there was the history of nervous exhaustion—of too much work and too little rest, telling on a nervous system unstable by heredity. With minute exactness he details his symptoms and analyses his miseries. In case he should overlook anything he comes armed with a slip of paper, a few notes of his case—"l'homme aux petits papiers," as the French physicians call a figure not unfamiliar to the consulting-room. The first symptom on his list is sleeplessness. He cannot sleep. There is no pain or any great discomfort, or anything in his surroundings to account for it; he simply does not sleep. He has tried everything. He has denied himself his afternoon nap in order to secure his sleep at night,—a great mistake, for in conditions like this *sleep brings sleep.* He has darkened his room and closed his eyes; he has lighted his candle and read his book; he has tried counting, repeating, saying his prayers; he has followed the ticking of the clock and thought of the humming of bees. Of course, following distinguished example, he has tried a glass of water on going to bed and an endless list of similar devices. He has tried a multitude of drugs, for some of which he has an intolerance by idiosyncrasy. Now he relies almost exclusively on sulphonal, which gives him sleep (generally on the following night), but which, he considers, is not without evil effects of its own. He spends his day in dread expectation of the coming sleepless night. Should he happen to sleep soon after lying down, he invariably wakes again in an hour or so. His sleeping is ushered in by sleep jerks, haunted by nightmare and dreadful dreams, and his wakening is accompanied by no feeling of being rested and refreshed. The insomnia, at first a con-

sequence, is now a contributing factor to his mental and physical prostration. He has head symptoms: one of the earliest of these was vertigo. He chooses the side of the street with railings to the houses that he may be able to grasp them should his giddiness come on. Now he suffers from headache, not very severe, but like a band round his head, or a weight, or a heavy hat pressed down tightly (helmeted headache of the "galeati" of Charcot). It is a day headache, not a night one. There is hyperæsthesia of the scalp. Intellectual work has become difficult, almost impossible; he cannot even write a letter. Once a man of action, of courage and resource, he is now pusillanimous and hesitating, and leans on others. There is an obvious condition of cerebral depression, a decrease of will-power, a feebleness of character, a diminished power of resistance. He is emotional to an extreme degree, and "breaks down" on the most trifling occasions. Once, sitting at the play, interested and amused, and surrounded by laughing faces, a cloud suddenly seemed to come across his mind, everything looked black, his prospects seemed hopeless, he lost his self-control, and burst into tears. He suffers from dyspepsia, for the most part of the atonic flatulent kind—the stomach rises into the thorax. There is exaggerated resonance over the whole abdomen from inflation of the intestine, and this distension interfering with the descent of the diaphragm has its effect on respiration. He complains of muscular debility and a vague feeling of lassitude. The grasp of his hand or his squeeze of the dynamometer shows notably less force than would be expected from a man of his muscular development. He has already said enough to stamp him a neurasthenic. But, continuing the investigation of his case, a second line of symptoms comes into view. There is a peculiarity about his manner—an excitability, an impulsive restlessness. He shows a marked tendency to hypochondriasis and, as already stated, is apt to take a pessimistic view of the whole situation. He is evidently in the habit of going about from one medical man to another, never weary of talking of himself and his ailments; but (and here comes an important point in diagnosis with reference to a possibility which could not fail to suggest itself) he listens reasonably and thankfully to words of encourage-

ment and advice. He leans on the opinion of his medical attendant. At times he exhibits peculiarities of gait that look almost like hysteria. He walks cautiously, with a stiffish spine and occasional peculiarities of movement, almost mimetic of some serious organic lesion. Besides the general weakness of his nervous and muscular system, he describes fibrillary tremors of the muscles and jerks of the limbs, as well as disorders of sensation, tingling of the feet and fingers. The knee-jerks and superficial reflexes are normal, as are the electrical reactions. There seem to be no pressure points or areas of exaggerated sensibility over the spine, but there is an evenly distributed increase of the general cutaneous sensibility. He is intensely sensitive to heat and cold and all atmospheric changes. The conjunctivæ are a little congested, the upper eyelids being slightly œdematous. The pupils are perhaps faintly unequal, but inequality is not constant. There is no retinal congestion. He is extremely sensitive to noise. There is constipation and a malodorous condition of the morning urine, which contains no albumen and no sugar. The tongue is furred. Palpitation is induced by the slightest excitement; a trifling movement or a meal may bring it on. The pulsation of the larger arteries is excessive and at times tumultuous. He watches with anxiety the throb of his carotids, and anxiously compares it with that of his nurse or friends.

Such is the case, and insomnia the symptom to be met. A hopeful prognosis may be given, inasmuch as in electrisation there exists an agent well adapted to meet both the symptom and the disease—a sedative tonic. Of course there is the usual initial difficulty; such patients are hyper-sensitive always, and shrink from a proceeding which they are sometimes accustomed to associate with "a shock." Therefore, by way of making a beginning, I passed the weakest perceptible faradaic current through my own body, and with my hand administered for one or two minutes to his forearm the mildest of labile applications. He at first shrank back, but soon admitted that it was not disagreeable. I asked him to come again the next day. He did not come for a week, and then only at the renewed request of his medical adviser. He then explained that, though

he was "no worse," and quite convinced that the electrisation was as mild as it could possibly be made, still the "exquisite sensitiveness of his organisation" was such that he had felt pricks and tinglings and "sensations" ever since. He was then prevailed upon to step into a bath having a temperature of 92°F., and with his consent a continuous current of a few milliampères was passed through it—foot electrode, anode; cervico-lumbar, kathode. This was very gradually raised to 50 milliampères for five minutes. He slept well that night. Of course he said it was the warm bath. Possibly it was, but it was the thin end of the wedge. During the next week he had four or five such baths with a gradually-increasing current (up to 150 milliampères) and a gradually increasing duration (up to fifteen minutes), without, perhaps, any marked improvement in his insomnia, but with a perceptible rise in his general level of health. This treatment was continued until February 18th, and resulted in a less frequent necessity for resort to sulphonal, his average of sleep during the last week of this period having been from three to four hours. Direct head treatment was then entered on. Using the hair as a rheostat, a continuous current cautiously raised to $2\frac{3}{4}$ milliampères was passed from the forehead (anode) to the nape (kathode) for a minute, followed by subaural application (anode) of five milliampères stabile on each side for half a minute. This was followed by labile anodic galvanisation (five milliampères) of the neck (cervical spine, back of ears, and anterior border of sterno-mastoid), the kathode being at the epigastrium. The whole proceeding lasted about five minutes. Between the first date of this application (Feb. 18th) and the end of the month a similar procedure was almost daily carried out, sometimes twice on his worst days. However prostrate and depressed on his arrival, he always on going away after such an application expressed himself as feeling better, brighter, and more equal to bodily or mental effort. This treatment, with slight modification, was continued, with the result that his average of sleep between Feb. 18th and Feb. 28th had risen to five hours, and he had not taken sulphonal since Feb. 18th nor any other drug, excepting a very occasional dose of bromide of potassium, which he has taken ever since the beginning of his illness. Between

Feb. 28th and March 24th this treatment, with occasional faradaic baths, was steadily pursued, but with decreasing frequency and duration, and by that time (March 24th), his average of sleep for the twenty-four days having been six hours, the treatment was discontinued—that is to say, after seven weeks of treatment, consisting of about thirty sittings and twelve baths, sleep was practically restored. Not only this, but the general health and moral condition were strikingly improved. Instead of dark forebodings and pessimistic views he talked cheerfully and hopefully of going back to work again. On April 1st the improvement was not only maintained, but was still progressive.*

Those rarer uses of the constant current bath, consisting of the introduction of medicinal substances, or the elimination of metallic impurities (" medication and de-medication ") must be considered. The possibility of both cannot be disputed. A case has been reported where an appreciable quantity of lead " which could have come from no other source than the tissues of the body," was found in the deposit on the copper plate. It has since been suggested that this might have come from a little solder discovered on the electrode. Inasmuch as the case upon which doubt is thus thrown constitutes the present writer's only experience, he prefers to keep an open mind, and can only refer to the paper read by M. Poey before the French Academy in 1855, which relates the classic and ever-quoted case of the electro-plater of Havana. This man suffered from an obstinate ulcer of the hand, stated to have been caused by the solution of nitrate and cyanide of silver into which

* 'Lancet," June 10th, 1893 (he resumed his professional work shortly afterwards, and when last seen, Oct., 1895, was in good health.)

it was necessary in the course of his occupation frequently to dip his hands. On one occasion it happened that he immersed his hands in the liquid before the object to be plated had been put in. The negative wire became covered by a metallic film. It was concluded, therefore, that the deposit came from the hands of the electro-plater. The operation was repeated in order to extract any metallic particles that might remain. Cure of the ulcer followed. Although this process of elimination rests on evidence which is very far from conclusive, still no opportunity should be lost of testing the question in a suitable case.

The treatment of skin diseases by electrical methods is one of great and growing importance. The material in possession of the writer does not enable him to deal with it in any satisfactory way so far as the constant current bath is concerned. Judging, however, by the few cases in which he has seen it used (urticaria and eczema), and by the effects in such cases of other forms of electrical treatment with which all are familiar, this form of bath would seem to deserve a patient and extended trial. For purposes of the present chapter and his own information, the writer has consulted special works on cutaneous disease, yet without adding materially to his information on the point in question. But amongst these works there lies before him a brochure on "The Bath in Diseases of the Skin,"* from which (p. 61) he ventures to extract

* "The Bath in Diseases of the Skin," by J. L. Milton, Senior Surgeon to St. John's Hospital for Diseases of the Skin,

the following passage :—" It will naturally be expected that I should say something of the galvanic bath. . . . I frequently employ them through the medium of a foot bath, one foot being placed on each handle, and the force being given by the 100 cell Becker-Muirhead used at the hospital, or a good-sized wheel magnet." Having noted the latter novel source of "galvanic" supply it is scarcely necessary to say that the attempt to gain light and leading from the volume referred to was not persevered in.

Lecturer on Diseases of the Skin, Member of the Harveian Society, Corresponding Member of the New York Dermatological Society, etc., etc.

CHAPTER IV.

THE CONTINUOUS DYNAMO CURRENT BATH.

When the source of supply is a continuous current lighting circuit, it must be safeguarded by a "reducer of potential." The best form of the latter instrument is the traversing interlocked shunt rheostat, fully described by the present writer in his monograph on "Current from the Main."* With continuous currents from a transformed system, it will be well to interpose a motor and make this drive by belt a small dynamo, which should not be fixed on the same metal bed plate.

Full details of the physical character and the chemical and physiological effects of the continuous current lighting circuit from central stations, will be found in the above-named essay. In this connection it is here sufficient to say that for therapeutic purposes the currents in question, if properly handled, do not differ in any material way from the current produced by the strictly uniform electromotive force of an ordinary Leclanché battery.

In using public supply currents for the purpose of the electric bath, the first consideration must be the paramount necessity for efficient insulation;

* "Current from the Main," London, H. K. Lewis, 1896.

and this necessity will apply equally to all systems of supply, whether continuous or alternating, direct or transformed. In the usual electrical applications security would be attained by standing on a very dry floor or, more certainly, on a varnished kamptulicon mat. But in the case of the water bath, connecting as it does with a good earthing device in the shape of waste pipes and water pipes, the case is altogether different, and certain additional precautions then become necessary. With these duly carried out effective insulation can certainly be secured. In the first place it is obvious that the bath should not be made of metal. Hard wood or porcelain are suitable materials, the latter by preference. The bath should stand upon glass mushroom insulators filled with a heavy resinous oil (similar to those used for insulating storage batteries) or it might be placed upon hard vulcanised rubber blocks. The inlet stopcocks for both hot and cold water should be placed at some distance from the bath, and in such a position that it would be impossible for the patient, when in the bath, to accidentally make contact with them. An insulating piece of porcelain or vulcanised rubber should be inserted in both inlet pipes between the stopcocks and the bath. If the waste pipe be attached to the bath an insulating piece should be inserted as close to the bath as possible. But danger may be even more easily and effectually averted by fixing directly below the waste outlet of the bath a shallow tank or sink to receive waste water from the bath, the waste pipe being attached

to this sink. Neither the tank nor the waste pipe should make contact with the bath.

The following diagrams show the electrical conditions that exist—for example, in a bath—when an earth connection is made, and illustrate the serious danger to which a patient would under such circumstances be exposed.

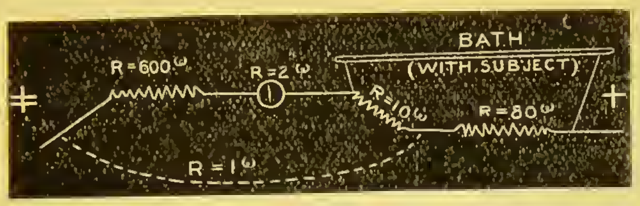

FIG 16.

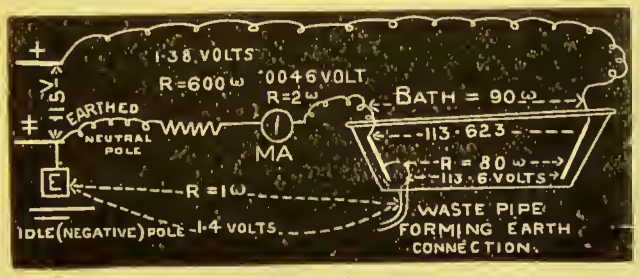

FIG 17.

115 volts is the full pressure of supply. There is one "series" R = 80 and there are two parallel branches (R = 600 + 2 + 10 and R = 1). Then the total resistance $= \dfrac{612 \times 1}{612 + 1} + 80 = 80{\cdot}998$, and the total current $\left(\dfrac{115}{80{\cdot}998}\right) = 1420$ m.a. The current in the respective parallel branches will be as 612 : 1—in other words, current being inversely proportional to resistance, and the milliampère meter being placed in the circuit of higher R (in the proportion 612 : 1), only 2·3 m.a. will be

registered, whilst the remainder of the total current (travelling *viâ* the circuit of low R. viz., the earth) amounts to 1417·7 m.a., and the milliampère meter fails to register any of this leakage current. But both circuits are common to the bath. Had the patient been placed in contact with the uninsulated (neutral) wire and the resistance been interposed between him and the insulated pole (positive or negative) he would not, even if placed in an uninsulated bath, have been in the circuit of any earth current. This would hold good only so long as the condition of the mains was good. Should a fault break out on one of the outer wires (positive or negative) the state of affairs would be in no way different from the case just considered. What, then, is the remedy for this risk? Clearly insulation. It should be taken as an axiom that the current from public supply mains should *never* be applied either as a shunt or direct to the patient without interposing between him and the earth an insulating substance of such a nature as would undoubtedly stand the full main pressure across it without passing a current of 1 m.a. In the case of three wire systems the "full main pressure" would be double that of supply, and in five wire systems four times that of supply. In dealing with public supply currents for medical purposes, the first and last word must be always *insulation*.

CHAPTER V.

THE "FARADAIC" BATH.

For an alternating current of that dissymetrical type known medically as the "Faradaic" (Fig. 12, p. 27), a strong induction coil is necessary, with a smooth and trustworthy method of current regulation. The latter will be best effected by the sledge arrangement in which the secondary can be gradually pushed over the primary which is fixed; and so the strength of the current can be gradually increased from 0 to its maximum. By increasing or decreasing the mutual induction of the two circuits the electromotive force will be correspondingly altered without altering the inducing current in the primary. By the insertion or withdrawal of an intensifying core a similar effect can be obtained, but this method is inferior to the sledge arrangement. Neither can the latter be profitably replaced by the method of decreasing the magnetising power by the "shielding" tube. A coarse but very effective form of bath coil known as that of Constantin Paul is commonly sold. It consists of a primary wire only. The regulation of strength is effected by means of a pivoted arm touching studs and thus being enabled to pick up (tap) various lengths of the coil wire. There is also a shielding tube which

by its withdrawal increases the strength of the current. In this instrument although there is only a primary wire the current is not only the direct inducing current interrupted, but inasmuch as the coil possesses a considerable amount of self induction, there is an extra current which being in an opposite direction at make, simply acts to cut down the battery current and almost to efface it. But acting as "a plus" to the current of break leaves the latter predominant, and in point of fact the only one that need be considered. But in such a coil the make and break currents are both "direct." Taking into consideration its physical character, the physiological effects of a current from such a source cannot be quite the same as those from the secondary of an ordinary induction coil. Still the two currents are used for the same class of cases and their therapeutic effects are not always to be clearly differentiated. These currents will be adopted on the same general principles as is the use of general faradisation in any other form. Strong muscle contracting currents will not be desired; such currents extended over the duration of a bath would exhaust muscle and irritate nervous centres. This point leads to a consideration of that most important factor in the character of coil currents the interrupter or contact-breaker. In the average English or German coil and especially in bath coils the interrupter does not receive sufficient attention. Rapidity of interruption ought to be variable according to the requirements in view and variable within a much wider range than that obtainable by the adjustment of

the screw of the ordinary spring. In order to obtain a smooth and uniform action the interrupting arrangement or "contact breaker" ought to be actuated from a special source. A good instrument ought to be supplied with a slow acting vibrator capable of seventy to a thousand interruptions a minute and "a fast spring" giving from 1,000 to 3,000 or 4,000 a minute. The rate of vibration obtainable should be sufficiently high to secure the sedative or numbing effects of such currents. The object of the bath is usually not so much to determine effective muscular action as to secure the nutritive and sedative effects of which it is demonstrably capable.

CHAPTER VI.

THE SINUSOIDAL CURRENT BATH AND ALLIED FORMS.

WITH alternating currents "from the main" a "Woakes," or "Miller and Wood's" transformer may be used; but it should be tested with at least the pressure of the primary mains between its primary and secondary windings before being installed for work. Under any circumstances with public supply currents, whether alternating or continuous, it is desirable to fix upon each pole of the therapeutic circuit a reliable magnetic cut-out. But if the supply be an alternating one it becomes a question whether instead of simply using the current through a transformer it might be desirable to use a small motor driving a therapeutic alternator. Control could thus be secured not only of electromotive force and frequency, but even of the shape of the electromotive force curve.

The effects of sinusoidal currents, or rather of those pseudo-sinusoidal currents obtainable from alternating light mains applied through the medium of the water bath, have been especially studied by Gautier and Larat, from whose writings the following remarks are chiefly taken:—Immersion varies from a quarter of an hour to 40 minutes, and beneficial results soon show themselves in an increased appetite, a general feeling of lightness and elasticity,

and often in an improved action of the intestinal canal. These authors therefore regard such applications as a good general stimulus to the functions of organic life — a "tonic" like fresh air, salt water baths, or hydro-therapeutics. This general tonic action, they state, is especially seen in chlorotic anæmia, where even after four or five baths appetite returns, the enfeebled intestine resumes its normal functions, palpitation and bruits disappear, and menstruation is re-established. Equally noteworthy is this tonic action in that form of neurasthenia known as "spinal"—the characteristic feebleness of the limbs, girdle pains, and weakness of the genital organs, often quickly and permanently disappear. But a great deal more is claimed for this bath than a mere tonic effect. In disordered states of nutrition and in certain "diatheses" the effect is to restore function to its normal type. This is effected partly by the tonic influence already noticed, and still more by that demonstrable increase in the nutritive exchanges which follows the treatment. In "strumous" conditions ("lymphatisme"), both of children and of adults, there is often a remarkable improvement. The same, and with even greater truth, may be affirmed of rickets. The authors in question regard rickets, not as a chemical derangement primarily affecting the bones, but rather as a condition dependent on faulty assimilation. And they come to this conclusion, inasmuch as by the treatment in question, rickety children, without the use of lime or iron, show a manifest improvement, an improvement the possibility of which no one can

doubt after the demonstrations of Segretti. The latter used the extra current of the faradaic machine. But the same effects are not less marked with the bath through which sinusoidal currents are passing. In cases of obesity the treatment by the latter method has been followed by improvement in health and decrease in weight, often permanent. Four cases of muscular atrophy of myopathic origin are recorded which underwent improvement by the same treatment. Rheumatism, especially in its muscular manifestations (lumbago and torticollis), was cured by one or two seances. Neuralgic pains of a rheumatic character, especially sciatica, do not show so rapid an improvement, but still no treatment presents better results. In simple sciatica, cure is relatively rapid (15 to 30 seances), a result which the writers consider good, in view of the fact that in all the cases given the sciatica had proved rebellious to other forms of treatment. In subacute and chronic rheumatism the painful articular swelling and muscular weakness and atrophy that characterise these conditions often yield to this form of bath. The same may be said of gout. When the attack ends the pain and swelling disappear much in the same way that they disappear under the use of the thermal waters of Aix-les-Bains. And if the treatment be carried out between the attacks the intervals become gradually longer and the attacks gradually shorten. Perhaps the most remarkable result that followed this form of alternating current bath was seen in eczema. In the case of a lady who was under treatment by these baths for chronic rheuma-

tism, but was also suffering from an eczema of 30 years' standing, it was noticed that the latter got rapidly well. The same has since then been observed in a number of other instances, and relapse is rare. The good effect in such cases must be dependent on improvement in the general nutrition of the body, rather than on any local action in the affected part, inasmuch as the bath led to disappearance of eczema of the face, as well as of the other parts of the body to which the current had direct access. Similar results, but less constant in their occurrence, have been observed also in urticaria.

The following case* will serve to illustrate the usefulness of the generalised application of the alternating light circuit current by means of the water bath, in a severe case of trigeminal neuralgia :—

A man, aged 53, had for about four years suffered from severe paroxysmal neuralgia of the second and third divisions of the fifth nerve. In September of last year he was, as he expressed himself at the time, "desperate" from it. It was relieved by five milliampères of galvanic anode—the details of which application need not here be entered upon. On several subsequent occasions the same proceeding had been successful, and at other times the pain had disappeared under the administration of Indian hemp. After some months of complete freedom from pain he again (on April 5) presented himself for electrical treatment. He said that for the past three weeks he had suffered "night and day." A variety of medicines, including Indian hemp, had been used without benefit. He described the pain as "plunging like knives," "stabbing," "seizing the roots of the tongue," and he altogether bore an expression of great suffering. During a paroxysm the face became fixed in spasm, and he vigorously grasped the left side of the lower

* "The Treatment of Trigeminal Neuralgia," by W. S. Hedley, M.D Reprinted from "The Lancet," June 2nd, 1894.

jaw, exercising powerful pressure with his thumb on the point of emergence of the mental branch of the inferior dental. Having examined the mouth without result for a probable "offending tooth," five milliampères of continuous current were locally applied for five minutes—the anode (an electrode of 4 c.m. diameter) over the seat of pain, and the kathode (14 by 8 c.m.) at the nape of the neck. This was without effect. By the simple expedient, however, of insulating the patient and "taking sparks" over the points of greatest pain it completely disappeared, and he went away smiling. A short-lived smile. Scarcely had he reached home when, within half-an-hour of the application, things were as bad as ever. Next day a similar application was followed by an hour's relief and a night's rest, but there was an immediate return of pain on getting out of bed next morning. Both as to symptoms and treatment this represents the history of the case for the next few days. On April 15, besides the electrical application, a tooth (third left lower molar) was extracted at the patient's request on the chance that there might be exostosis or other undiscoverable condition of the root. After half-an-hour the pain returned with much increased violence. On the 17th the condition of the patient having in no way improved, and despairing of results from localised applications or drugs, the hydro-electric bath* was administered at a temperature of 98° F. for fifteen minutes—the current being obtained from an alternating light circuit having a potential of 100 volts and 8,000 alternations a minute. Its strength was regulated simply by means of a sponge rheostat, with a sixteen candle-power lamp in circuit. The effect was striking and immediate. From a condition of intense suffering on entering the bath the patient found himself on emergence absolutely free from pain. Seven such baths were given on the same number of successive days—but from the first, with the exception of a slight "bruised" feeling for a few days, the freedom from pain has been lasting and complete. The patient says that he has felt from the first "a different man," and stoops down to lace his boots without misgiving—a position which before would inevitably have induced a paroxysm of pain.

* Dipolar.

Now, if instead of the above treatment this patient had been subjected to operation, the operation would with justice have claimed the result. As it is, this may be fairly credited to the electrical treatment. It is idle to talk of "cure" in such cases. The important questions are: How long will immunity from pain continue, and how far will the same procedure be successful on recurrence? It is more than possible that this patient may eventually have to be sent for operation, but in the meantime it is at least satisfactory to think that, before the more heroic remedy is resorted to, there are yet other weapons in the varied armoury of electro-therapeutics.

The following table has been kindly sent me by Dr. Lewis Jones from recent records of the electrical department of St. Bartholomew's Hospital. It gives a good idea of the relative efficacy of the different forms of bath in a few cases of sciatica:—

A.—GALVANIC BATH ANODE TO FOOT.

Sciatica {
1. Louisa F., 41. Twelve baths. 200 m.a. Cure. General health improved much.
2. Louisa F., 41. Eight baths. Cure.
3. Henry G., 64. Relieved after four baths; returned five months later; eight baths, but no relief.
4. Henry G., 64. Cure after four weeks; eight baths.
}

5. M. Gonorrheal rheumatism. Nine baths. No definite improvement.
6. F. Rheumatoid arthritis. Twelve baths. Slight improvement.

B.—FARADAIC BATH.

Sciatica {
7. H. B., male, 43. Seven baths, induction coil. Cure.
8. Male, 47. Seven baths, induction coil. Cure. A long previous treatment with anode to thigh (without baths) ineffectual.
9. F., 50. Rapid cure. Number of baths not given.
10. Thos. H., 25. Galvanic baths first, then anode to thigh; then faradaic bath. Last most useful; relieved.
}

C.—Alternating Mains.

Sciatica:

11. R. E., 60, male. Fifteen baths. Sinusoidal. Cure.
12. F., 30, female. Four baths. Sinusoidal. Cure.
13. F., 30, female. Same patient, with general rheumatic pains; two years previously had galvanic baths (twelve) and was cured.
14. W. H., 23, male. Five baths; much relieved. Left London. Wrote a week later that improvement continued.

15. G. T., 25, female. Severe neuralgia (cervico-brachial). Ten baths. Sinusoidal. Cure. Old standing case.
16. F. Rheumatoid arthritis. Twenty baths. No improvement.
17. F. Rheumatoid arthritis. Twenty baths. Doubtful.

CHAPTER VII.

THE ELECTRIC VAPOUR BATH AND THE ELECTRIC HOT AIR BATH.

The so-called electric vapour bath scarcely requires mention here. It is not in any strict sense an electrised bath; it is simply an application of electricity to a patient in a vapour bath. The best and most suitable apparatus for this purpose is that known in hydro-therapeutics as the steam box bath, in which the patient sits, the head not being included. It consists of a steam-tight box, with a coil inside and a steam generating apparatus outside. The steam can be admitted into the cabinet by a valve or allowed to escape outside. In the latter case the arrangement becomes a hot air bath (*étuve sèche* of the French). The seat of the cabinet is in connection with one pole of the battery, and the other pole is attached to a plate below the feet, or is applied to some special portion of the body, according to the effect desired. The arrangement to be used will be vapour or hot air, according to circumstances, remembering only that the hot air can be borne at a higher temperature than the vapour bath, radiation, of course, being greater in the former and skin action more profuse. The

vapour bath may be administered at, say, 96° to 104° F., or exceptionally up to 112°; the hot air, if *dry*, can be borne at a much higher temperature. It may also be remarked that in the vapour bath a higher temperature can be borne than in the hot water bath, but for a shorter time, since the circumambient vapour interferes with heat radiation from the body (Shelley).

If the above arrangement be not available a very efficient substitute may be extemporised by seating the patient on a chair with a large covered electrode on it, placing another under his feet, covering him over, except head, by a large blanket and mackintosh, and placing a couple of red-hot bricks in a pan of water. An extemporised hot air bath is managed in the same way, excepting that a spirit lamp only is lighted beneath the chair. By means of placing a vessel of water over the spirit lamp the body becomes subjected to the action both of hot air and steam. The process ought to last about fifteen minutes and be followed by a light douche, electrised or otherwise, and a good rubbing.

By diminishing skin resistance these methods assist to some extent the process of electrisation; but what is of very much greater consequence they have a directly beneficial effect of their own on the morbid condition (neuralgic, or rheumatic, or stiff joint affection), in which their co-operative influence would probably be sought. The usual contra-indications to their use, such as diseases of the circulation, fatty heart, and conditions of old age and

debility, will, of course, hold good whether accompanied by electricity or not.

Purely local effects by vapour or hot air baths can be secured by means of special "receivers" adapted to special parts of the body.

CHAPTER VIII.

THE ELECTRIC DOUCHE.*

THE electric douche has proved itself a therapeutic agent of undoubted promise. Yet in the way of accurate experimental investigation singularly little seems to have been attempted. Sufficient, however, has been done to demonstrate its electrical power and its therapeutic possibilities. The object of the present chapter is to detail the writer's original experiments bearing on the question, to carry forward the inquiry in the light of a further experience, and especially to enter into greater detail as to how the method may be best systematised and applied.

It has been shown in the foregoing pages that as a means of applying electricity to the body the water bath possesses many unique advantages. That not only is it the most agreeable, but of all others it is

* All the tables and much of the explanatory matter have already appeared in the "Lancet" and in the "Journal of British and Foreign Health Resorts." These articles were the outcome of an experimental investigation undertaken (in the absence of any literature on the subject) by the present writer for his own information.

the method that best deserves the name of general electrisation. Its efficacy, however, depends in most cases on a general and distributed action rather than on any strictly localised effects. The electric douche has been devised as a means of retaining the advantages of the electro-hydriatic method, and at the same time of presenting facilities for strict localisation and accurate dosage, and securing the advantages of a labile as well as of a stabile action.

Attempts have been made to attain the above ends by the use of spray or vapour; but such attempts have failed, because the conducting medium had been so broken up and disintegrated that it ceased to act as a conductor. It is evident that any stream of conducting fluid can retain its conductivity only so long as it remains whole, continuous, and unbroken. Spray is composed of numerous small particles sometimes appearing as many fine continuous streams, but actually possessing no real conductivity in the sense that applies to the matter under consideration.

The method of application, apart from certain non-essential details, is much of the nature of what would be known in hydrotherapeutics as the "movable jet douche (douche mobile), and the nozzle is so arranged that the electrised stream escapes in the form of a more or less condensed jet or jets,* which, with a certain minimum of pressure,

* The "Ball nozzle" may be used with advantage.

remain unbroken and continuous for a reasonable distance after emerging from the pipe, and therefore for that distance retain their electric conductivity. It is obvious that there must be some means of regulating temperature and pressure. With this arrangement one pole may be placed by means of a large electrode in contact with some indifferent part of the patient's body, while the other pole is connected to the internal metal of the douche, with the result that when the douche is set in action the second pole is brought to the patient by and in the fluid, and may be concentrated as a single jet, or distributed as many small jets. The fluid is, in fact, the second electrode.

It was necessary to inquire, by direct experiment, how much current this water conductor carries and how much enters the body of the patient. The following experiments are necessarily only a selected few, but a sufficient number of results are quoted to give some general ideas. It may be mentioned that, permanent water pressure not being available, a hand pump, drawing from a suitable vessel, was used for the douche, which was fitted with a nozzle or rose (having its outer edge insulated with india-rubber) of the size mentioned below. The electric apparatus consisted of a Leclanché battery of seventy-four cells with a milliampère meter in circuit and a fair-sized induction coil. One pole was attached to a large electrode on which the patient sat, and the other pole connected with the metal of the nozzle or rose, well insulated wire being used for

the connections. The following results were obtained:—

TABLE A.

Plain water at 98° F., continuous current.

Nozzle.	E.M.F.	Pole to Douche.	Distance of nozzle from body.	Current passing.
1. ¼in. jet (single) ...	75	—	1·5in.	5 milliampères.
2. ¼in. jet (single) ...	,,	,,	0·5in.	15 milliampères.
3. Rose 2in. in diameter, 49 perforations	,,	,,	1in.	5 milliampères.
4. Single jet	,,	+	18in.	Deflection (taken on reflecting galvanometer) right off scale. Probably quite 100 microampères.

TABLE B.

Salt water (½lb. to 7 gal.), temperature 98° F., continuous current.

Nozzle.	E.M.F.	Pole to Douche.	Distance of nozzle from body.	Current passing.
1. Rose	75	—	1·5in.	7·5 milliampères.
2. Single jet	40	+	18in.	20 milliampères.

TABLE C.

Plain water, temperature 98° F., alternating current.

Nozzle.	E.M.F.	Pole to Douche.	Distance of nozzle from body.	Current passing.
1. Rose	x	+	1·5in.	Subject cried out "Stop" Milliampère meter (alternating current) in circuit did not register.
2. Single jet	,	+	12in.	Noise marked in telephone. Subject felt current.

Several readings were taken with alternating current and salt water, all showing that the effect was much stronger with salt water than with plain. These experiments seem to show that electricity can be imparted to the human body by means of the electric douche, provided that sufficient electromotive force be used and the stream of fluid be continuous. Table B shows that when salt water is used strong currents may be passed over considerable distances with a very moderate electromotive force. Table C shows that by using coil currents which always possess a comparatively high electromotive force, as much current as a patient can comfortably bear may be passed over many inches of space. Attempts have recently been made to associate electrical treatment with certain mineral water cures, probably not to the advantage of either. Indeed it appears that such attempts have already led to much of that loose and inaccurate work which has over and over again brought electrotherapeutics into disrepute. An essay "Sur une nouvelle méthode d'application des courents electriques a l'aide de l'eau et de la vapeur d'eau," par le Doct. P. Guyénot,* may be cited as an instance of this. It appears that this writer uses two douches or jets. Whilst one is directed upon the body of the patient the other is directed downwards upon the cemented floor of the cabinet until a sheet of water is formed surrounding the patient's feet. This constitutes the second or in-

* "Revue d'Electrothérapie."

different electrode. Without commenting upon this arrangement as being a most unnecessary application of douche to the floor, the point to which exception is now taken is the "discovery" that not only water but the *moisture of air* will conduct electric currents. The writer in question found that the wire connecting one pole of the induction apparatus to douche No. 1 having been detached from the latter, rolled up and hung about 3 metres from the patient (its other extremity being still connected with the coil) and the second wire still attached to the second pole of the induction apparatus as well as to the metallic part of the second douche, and the cabinet full of a thick cloud of watery vapour—behold an electrical current was established! "The patient said he felt it," and the fact it is stated was further verified by a galvanometer and a constant current. "Evidently therefore the circuit was completed by the watery vapour surrounding the body of the patient."

Before publishing this conclusion it might have been well if the writer, leaving behind him his douches and cabinets and moisture-laden air, but taking with him a large coil and (say) two bichromate cells to drive it, had proceeded to a dry room and there carried out the following experiment:—Attaching a conducting wire by one of its ends to the secondary of the coil, the other end of this wire being free and the other pole of the coil being "idle"—let the coil be put into action. If now the free end of the wire be touched by the finger a current is felt to pass each time contact is

made. The patient slightly insulated might then take into his hand an ordinary electrode attached by its rheophore to one (secondary) pole of the coil. If now the operator lightly touch the patient's forehead a distinct electrical sensation is felt. Or let the idle pole of the coil be attached to a gas or water pipe, and the patient insulated as before, hold the other pole, then, if his arm be touched by a second person standing "to earth," a distinct effect just short of muscular contraction will be produced. These are not mere experiments modified in a variety of ways, they are useful in practice. But the present point is this—that in all these cases there is a circuit completed, one pole is "idle" and —where the moisture-laden air? A few experiments with this "idle pole" work might have suggested to the operator that when he hangs up his wire or carbon plate attached to one pole of the coil, he is perhaps in reality only making a good "earth" for his idle pole—(*via* ceiling, wall, and floor) and that the earth rather than the watery vapour is the medium of conduction. But there is the control experiment. It is stated that when a galvanic battery was substituted for the coil, a galvanometer placed in circuit showed a deflection. Nothing is stated as to the character of this deflection. Was it a steady and persistent rise denoting leakage—or was it a "kick" denoting some possible capacity effect, or was it neither, or only an error of observation? Be the explanation what it may, the following simple experiment will exclude the one (watery vapour conduction) offered by the

writer of the essay referred to. Let the experimenter provide himself with a tea-kettle, boiling, and with a good jet of steam issuing from the spout. Then taking a metal tube say 2in. long by 2in. in diameter, connect it with one pole of a continuous current lighting circuit having a pressure of 115 V., a galvanometer and a R. of say 600 ohms being placed in the circuit. Hang the tube at the end of the kettle spout so that the steam issuing from the spout becomes condensed in the metal tube and assumes the condition of "a dense cloud of watery vapour." To the other pole of the source of supply attach by its rheophore an ordinary metal disc electrode having a wooden handle. Now holding this handle, let the watery vapour driven through the tube play upon the metal disc held at say $\frac{1}{4}$ inch or as near as possible to the tube without touching it. The galvanometer will not betray the completion of a circuit by the very faintest movement. How then can it be hoped to convey a therapeutic current by such means?

The current-carrying capacity of the electrised douche having been established, a brief survey may be taken of its physiological effects and therapeutic applications. An analysis of the action of the electric douche shows three factors to be at work. (1) The action of the simple douche directly influencing the skin and indirectly affecting deeper structures. (2) The electrical action on the skin direct and indirect. (3) The direct influence of an electrical current passing through the body. As to the first, for the present purpose it may be con-

sidered that, broadly speaking, the simple douche is used to obtain a controlling influence over the circulation and distribution of the blood, to increase the "tonicity" of muscles, even to stimulate them into contraction, and to influence nutritive processes by the mechanical stimulus of concussion. It seems to be owing to modifications of these three classes of effects that the ordinary douche is regarded as a "nervine tonic," "an absorbent," and a "derivative." It is known how effective an agent for similar purposes is peripheral electrical excitation. It seems evident, therefore, that the hydriatic and electrical procedure may well go hand in hand for such purposes. And not only this; it is known that the ordinary douche increases cutaneous sensibility, and that under its influence muscles become more susceptible to nervous stimuli. It may thus be an effective precursor, preparing the ground for the influence of the electrised stream, and putting the tissues into a condition of receptivity, so to speak, for electrical stimulation.

Now, looking further into the phenomena of peripheral electrical stimulation, it is stated (Landois and Stirling) that "Weak electrical stimulation of the skin (of the frog) caused at first contraction of the blood vessels, especially of the mesentery lungs and web, with simultaneous excitement of the cardiac activity and acceleration of the circulation. Strong stimuli, however, had an opposite or depressor effect, with simultaneous decrease of the cardiac activity." Other observations show that contact with the skin causes pressor effects, while painful impressions produce no

effect. "Pinching the skin causes contraction of the vessels of the pia mater of the rabbit . . . cold dilates the vessels. . . . These results are due partly to pressor and partly to depressor effects. But the chief cause of the dilation of the blood vessels is the increased blood pressure due to the cold contracting the cutaneous vessels"* (Landois and Stirling). The secretions of the liver and kidney are affected through the nervous system by its modifying the pressure and velocity of the blood current in them, and also the hepatic secretion may be further influenced by those nerve fibres which, according to Pflüger terminate directly in connection with liver cells.

Such considerations bring home to the mind how far-reaching may be the results of cutaneous excitation, whether the stimulus be mechanical, thermal, or electrical. Often it will be that the power of electrisation to reach an internal organ will depend not on any special action inherent in and peculiar to an electric current, but upon an influence which, having its starting point in the electrical stimulation of some surface-area and travelling perhaps by nerves of common sensation, will strike the spinal cord at some special spot, and reflected thence will find a route by filaments of the sympathetic to some particular organ, an organ thus in neural relationship, through this special segment of the cord, with that area of cutaneous surface which was the site of the electrical stimulation. Such a process not only throws light on the rationale of peripheral electrical

* In this connection the observations of Nothnagel and the experiments of Rumpf on vascular reflexes may also be referred to.

excitation, and especially on the action and uses of the electrised douche and Faradaic brush, but it is one of the many points which, if duly weighed, tend to a wider conception of the entire question of treatment by electrical methods. The third factor in the electric douche is electrisation pure and simple. The fluid, acting as an ordinary electrode, passes a definite measurable amount of current through the body, and so far resembles an ordinary electrical application.

Although the apparatus necessary for the electric douche need not be elaborate nor complicated, there are certain essential details of construction which must not be lost sight of, and without which not only is its efficiency impaired, but the risk to operator or patient of getting a shock becomes by no means inconsiderable. The main requirements are somewhat as follows:—(1) A proper mechanical arrangement to secure that the fluid conductor shall pass out in unbroken streams or jets for a sufficient distance to conduct the electric current to the patient's body. Irregularly-shaped orifices will often to such an extent break up the column of fluid, even when issuing at considerable pressure, that its conductivity becomes practically *nil*; or, as sometimes happens, it is so intermittent that the current passes in a series of jumps, which are worse than useless for the purpose in question. Further, in the case of "rose" nozzles, if the size of the orifices fall below a certain gauge relatively to pressure, the issuing jets are too fine, there is no continuity of stream, and consequently no electrical

conductivity; or, again, if the orifices be not all of the same diameter, irregular conduction will result. (2) Careful attention must be paid to insulation. Want of due care in this point will soon be brought to the notice of those concerned by the unpleasant reminder already adverted to. When it is considered that currents of a fairly high electro-motive force have to be used for the douche and that nothing is more probable than the occurrence of some unexpected and perhaps for the moment unavoidable movement of the patient, whereby the instrument comes in contact with his skin, it is evident that unless the metal nozzle be well insulated a violent, perhaps a serious, and certainly an unnecessary shock will follow. Attention to insulation is also necessary in connection with the metal pipes and taps which control the water supply, in order that electrical leakage may be avoided. The apparatus consists of a short length of flexible rubber tubing, having an inside conducting wire, one end of which is brought out and connected to a terminal about two inches from the brass union which joins on to the supply pipes. The two inches of rubber tubing thus interposed between the metal pipes and the conducting wire act as effective insulation at this end of the arrangement. The other end of the internal wire is soldered to the inside of the metal screw, to which different nozzles are attached. The nozzles are of two kinds, one a single "jet," for current concentration, the other a "rose," for current diffusion. Each nozzle has an inner base of brass

covered with a sheath of vulcanite, which projects one-eighth of an inch beyond the brasswork. The orifices are true circles, and their metallic surfaces carefully smoothed, so that the issuing columns of water are kept intact for a considerable distance. It will be seen that perfect insulation is thus secured at all points, and even if through accident the nozzle does approach too near the patient, it is the insulating vulcanite, and not the conducting metal, that makes the contact.*

By the use of such an apparatus it has been found that, with the ordinary domestic water supply, continuous currents of useful strength may be passed with an E.M.F. of 50 to 60 volts from a battery of 40 Hellesen cells when the nozzle is held several inches from the patient. Alternating currents from a fair sized bath coil pass through a much greater distance. Reference to the foregoing tables of experiments shows that if saline or other special conducting fluids be used the distance through which the current passes is, as might be expected, much increased.

There was a time, in the days of "brutal hydrotherapeutic empiricism," when both physician and patient had a (not altogether inexplicable) dread of the "hydrostatic douche." This, however, has given way before a more enlightened method of administration, and the douche is now acknowledged to possess stimulating and alterative properties of no mean order. It seems not unreasonable therefore to suppose, even if clinical experience

* Splashing may be effectively prevented by the use of waterproof curtains suspended round the bath.

were not forthcoming, that in the combined electric and hydriatic procedure there is available a therapeutic agent of considerable power. It claims that, according to variations in temperature, force, and duration, it may be resorted to as an agent more gentle and adaptable than even the "electric hand" of the physician, or it may be made to become so potent and concentrated as to prove a veritable electro-hydriatic moxa. It presents itself as a means of general electrisation by bringing the various parts of the body successively under its influence; it claims an action that may be strictly localised, and further offers itself as a means of producing, through various motor inhibitory and secretory reflexes, those influences on nervous centres and glands which can undoubtedly be brought about by other and more painful methods of peripheral electrical excitation. If it can establish claims of this kind a field of usefulness lies before it in a class of cases which readily suggest themselves. When, for example, a general refreshing effect is sought, or a stimulating action on circulation and nutrition, or when it is desired to effect alterations in morbid conditions of blood pressure (which there is every reason to consider is very freely influenced by cutaneous stimulation) this douche becomes a suitable procedure.*

* It is interesting to remember that in electrical writings of more than 100 years ago, and while the static form was the only kind of electricity in use, we find electrical applications mentioned as curative of baldness and useful in promoting growth of hair. Few who work with electricity in medicine have not noticed this and

The action of the electric douche as a means of electrisation by bringing the various parts of the body successively under its influence, and as a local application by bringing it to bear on any special part, have already been referred to. Used in this way, it will not fail to prove itself a nervine tonic "heightening cutaneous sensibility and quickening motor excitability." It will influence nutrition and absorption by its control over the distribution and circulation of the blood current. It will act favourably on local diseases such as chronic joint affections, and promote absorption through its influence on the circulation. Its usefulness in states of general debility and malnutrition, neurasthenia, spinal debility, exhaustion, and any case in which want of "tone" is the prominent feature, needs no showing. These effects will be brought about in more ways than one, partly by the ordinary action of an electric current passing through the body, and partly by the enormous range of reflexes that, by so effective a method of cutaneous stimulation, are brought into action; and not least, perhaps, by the direct neural connection known to exist between special skin areas and internal organs.

perhaps availed themselves of it in practice. But it may be hoped that the day is far distant when some enterprising Figaro will see his way to acting on this hint and electrising his "hot and cold head douche." It would add a new and real terror to the ordeal of hair-dressing if in addition to the usual question, "Shampoo?" the further query, "Electrised?" came always to be added; although it is impossible to stifle the conviction that such a procedure in proper hands would prove a better "application for the hair" than any of the numerous "restoratives" of the tribe of Macassar.

Its adaptability to some forms of internal application cannot fail to suggest itself. An ordinary douche is frequently resorted to for its tonic, stimulating, sedative, or germicide properties on certain cavities and organs. Consider, as an example, a uterine displacement dependent on an enfeebled condition of the organ, or a relaxed state of the pelvic floor. The useful effects of faradaic or galvanic treatment in such a case are known. This applied by means of the douche electrode adds to the mechanical and thermal or medicated action of the ordinary douche, the powerful additional factor of electrical stimulation. The external auditory meatus, uterine cavity, bladder, vagina, naso-pharynx, and even the cavities of discharging abscesses, are all open to its influence by means of the most simple mechanical contrivances. Any arrangement of insulated metal tubes with suitable interchangeable nozzles may be adopted according to individual ideas and special requirements. Dr. M. Cleaves has devised several useful and ingenious instruments for these purposes, which will be described in the following chapter.

Recent therapeutic experiences of the writer leave no doubt in his mind as to the usefulness of the electric douche. He has more than once called it into requisition for the peripheral part of the treatment of old-standing paralyses of central origin. He has found it a most useful adjunct to other electrical methods in the treatment of that ensemble of symptoms known as neurasthenia, and in several cases of anæsthesia it has been found of such

service that, so far as anæsthesia is curable at all, the electric douche may be regarded as a sovereign remedy. The following case will serve to illustrate its usefulness as a peripheral stimulant.

B., aged 30. Paralysis of two months' standing, right forearm extensors and supinators involved, wrist drop, R.D. sensation impaired, "woolly" feel and numbness, especially over the distribution of the radial. One or two rather painful points in the course of the posterior interosseous. History and symptoms show it to be a case of pressure paralysis (musc. spiral). Was attacked shortly after having lain in an awkward position during several hours when intoxicated. Has taken medicine for two months. Electrical treatment now entered upon by weak currents ($\frac{4}{16}$), anode stabile on each painful point, five to ten minutes, cathode large indifferent electrode. After two or three weeks, no improvement; at the end of one month (twelve sittings), slight improvement perceptible. Powerful peripheral stimulation was then resorted to; at first by "single pole" treatment, that is to say, the patient being insulated and holding one pole of a large coil, had sparks taken from the arm. This was alternated with the electrised douche, and improvement followed with surprising rapidity, the cure being complete in eight weeks (twenty-five sittings) from the commencement of electrical treatment.

CHAPTER IX.

LOCAL HYDRO-ELECTRIC APPLICATIONS.

LOCALISED applications, whether by douche, by water introduced into cavities, or by local immersions, depend, for their efficacy, chiefly on details of apparatus. The local electric bath, *i.e.*, immersion of any special part or parts of the body in water contained in suitable receivers and electrised with the form of current desired, needs no further discussion. Local applications to cavities of the body, whether by an electrised stream (douche) or by water filling a cavity and electrised, may be considered together, as the same apparatus is suitable to both. The most important application of this method is the rectal douche—"electric injection." There is an almost endless list of monographs, chiefly French, on the electrical treatment of intestinal obstruction. At first, the faradaic current, with Duchenne as its exponent, had no rival in the field. But later Leroy d'Etiolles (1876) and Boudet of Paris (1882), came to the conclusion that intestinal contraction can be directly induced "only by slow excitations of the continuous current." The latter seems now to be in the ascendant, and there is a

physical and physiological reason why, dealing as it does in this case with unstriped muscle, the continuous current should be the more effective stimulus. Not that peristalsis of the intestine of a healthy animal cannot be produced by faradisation, but in those conditions of diminished excitability which are always theoretically present in intestinal obstructions, the constant current shows its superiority. This, according to Larat, may be demonstrated by artificially producing a kind of paresis of the intestine of an animal by distension with air. It can then be seen that, after faradaic excitability is lost, the constant current still continues to act. But, notwithstanding this, faradisation has an excellent record in the treatment of pseudo strangulation and fœcal obstruction. Amongst the many cases illustrative of this, there are two recently related by Dr. Althaus.* The first is that of a man suffering from obstinate constipation. Nothing in the shape of a solid or liquid motion had passed for ten days. The abdomen was much distended and tender. There was loss of appetite and a degree of collapse, sunken face, and small feeble pulse. The primary of an induction coil was used for twenty minutes by means of an insulated sound with a free metallic end. This was done at 10 a.m., and on the same evening there was a copious motion. The second case is that of a lady, aged 57, who had all her life suffered from obstinate constipation, which she thought had "been brought on by living on biscuits at school." A week or ten days had often

* "British Medical Journal."

passed without any action of the bowels, but she seemed none the worse for this, until the occasion in question, when, after eight days of constipation, there was found to be great tenderness and distension of the abdomen, with bilious vomiting and prostration. The same treatment was carried out with the same successful result. On the other hand, Boudet, and after him Larat, have had highly satisfactory results with the continuous current. The former, in a total of 50 cases, succeeded in clearing the intestine in 70 per cent. The latter, in 230 cases, was successful in over 40 per cent. The difficulty of applying the continuous current lay in the difficulty of avoiding escharotic effects at the active electrode. This continued to be an objection until Boudet devised the hydro-electric method—"the electric injection." For this procedure the requirements are the following:—(1) A battery of about 50 Leclanché cells or a supply from a continuous current electric lighting circuit, governed by a "reducer of potential" on the shunt principle. (2) As the indifferent electrode, an Apostoli pad or a large metallic plate 9 by 12 c.m. (or two of these) covered by a layer of agaric and camel skin. (Larat). (3) An ordinary irrigator containing strong saline solution. (4) An active electrode for insertion into the rectum and capable of reaching as high as the sigmoid flexure. This long curved insulated electrode is so arranged as to carry a stream of water from the irrigator, as well as a wire attached to one pole of a battery to convey the electric current. The water is thus electrised, and,

filling the bowel, carries the electric current to the intestinal wall. So far as the latter is concerned, the water is the true electrode. Dr. M. Cleaves has devised a most useful instrument for this purpose, of which the following is a drawing taken from

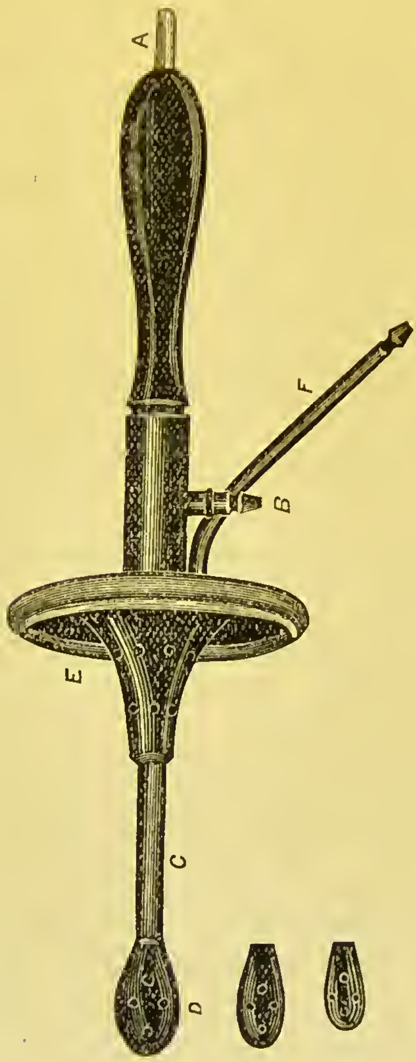

Fig. 18.—Vaginal Electrode.

Fig. 19.—Rectal Electrode.

that writer's monograph:—It is explained that "this and the other electrode figured, are of hard

rubber, and constructed with platinum wire for the conducting medium, which latter extends from the point at which the water enters the electrode to within a quarter to half an inch of the end of the perforated rubber tip." A suitable quantity (1 to 3 quarts) of salt water having been placed in the irrigator, the abdominal pad having been adjusted and attached by a connecting wire to the battery, and the active electrode having been introduced the procedure (following Larat) is this :—The active rectal electrode is connected up to the positive pole of the battery by a wire, and to the irrigator by a tube, the cock of the irrigator is a little opened and half its contents are allowed to pass slowly into the intestine. The strength of the electrical current will depend on the state of the patient and the probable cause of the obstruction. The intensity may be 10-20 m.a. or even more. The length of time during which the current is allowed to flow will be from five minutes to twenty minutes. In many cases, such as pseudo strangulation and fæcal obstruction, it is sufficient to use the continuous current without reversal or interruptions, but "when there is an obstacle to overcome it is necessary to add stronger excitation." In the latter case after the current has passed for five or six minutes it should be reversed by first bringing the needle to zero and again raising the current to its former intensity. By this "an intestinal contraction is almost always produced." When the patient can no longer control the action of the bowels the operation must be suspended, and he

must make efforts at defæcation. Then one of these three things will follow. Either an abundant evacuation will take place, or there will be only some liquid matter and gas, or the injection will come away hardly coloured. In the last two cases another application must be made, but not until seven or eight hours have elapsed. Having made three applications in twenty-four hours without success, further attempts by this method must be discontinued. Such is the procedure as laid down by Larat, and it is here detailed very much in his own words. He, of course, adds that in unsurmountable obstacles such as ileus or twists of the intestine by adhesion the only remedy is operation, but that in the case of a foreign body in the intestine or a tumour where the obstruction is not absolute, paresis of the intestine, pseudo strangulation, constipation, and fæcal obstruction, the procedure in question is likely to prove successful. But in point of fact on being called to a case of obstruction of the bowels with the abdomen distended and tender, some collapse and a feeble pulse, an accurate diagnosis of the cause of the obstruction is usually almost impossible. Therefore in all such cases after a purgative and enemata have failed, and before resorting to any surgical operation, the electric injection ought to be used; and used with all possible care in view of the fact that failure involves an operation whose mortality, even with every antiseptic precaution, is but little under 60 per cent. It has been urged against the method that in one or two cases an autopsy has revealed

gangrenous patches in the intestine, and the electricity has been blamed. It is difficult to see how, with a measured current carried to the bowel by the means in question, such a result could occur. Still, although almost certainly in the case mentioned the occurrence was the result of the disease and not of the treatment, the possibility of such an accident must be admitted. Dr. Cleaves draws attention to the usefulness of this method, not only in intestinal occlusion, but in constipation from atony; in intestinal catarrh; in enteritis, simple, pseudo-membranous or follicular; in chronic thickening of the mucous membrane; and in chronic diarrhœa due to fermentative conditions. In such cases 5-10 or 20 m.a. may be used with one to three quarts of lukewarm salt water in the irrigator. Experiences with the electric enema led Dr. Cleaves to design an electrode for the vaginal douche, shown in the figure, which in the hands of its inventor seems to have proved highly satisfactory in exudative inflammations of the pelvis, as well as in diseases of the vulva and vagina, "in vulvitis, pruritus vulvæ simple and diabetic, eczema of the vulva, chronic vaginitis, gonorrhœal vaginitis, erosions of cervix, relaxed and congested conditions of uterus and vaginal walls," and in leucorrhœas and displacements dependent on the latter conditions. It has also been found a useful supplementary measure to assist "intra uterine applications in fibroids, endometritis and salpingitis." When faradaic applications are indicated the douche electrode "is found extremely tolerable." Dr. Cleaves then draws

attention to the applicability of the douche to cataphoric medication in bladder trouble and gonorrhœal infection, in chronic cystitis, atony, and dilatation. For the bladder an intensity of 5 to 20 m.a. might be suitable. An instrument constructed of hard rubber and "similar to the ordinary two way catheter used for vesical irrigation with a third branch for the battery attachment," has been devised and described by the same author, who goes on to say that in negative hydro-electric applications with a saline solution every indication for the washing out of vagina, bladder, and all infected tissues with an alkaline solution is abundantly met. And then by the cataphoric douche the medicament, whether copper sulphate, bichloride of mercury, zinc sulphate, etc., can be driven directly into the submucous structure of the tissues about the urethra. As a nasal, post-nasal and oral application, when the ordinary douche is found useful the local electric douche would doubtless prove of greater service, but no very large number of useful experiences are yet forthcoming. The following case related by Dr. Cleaves in the same monograph which has been quoted throughout, may be cited. The diagnosis was "atrophic rhinitis with thickening of left Eustachian tube and drum. Treatment: In all, thirteen hydro-electric applications, negative, slightly saline (one quart), have been administered to ear at intervals of four and five days, current strength 4 to 6 m.a. Occasionally . . . the indifferent electrode was the copper sound at the mouth of the Eustachian tube, at other times the ordinary elec-

trode (15 square inches) at nape of neck . . . For the atropic rhinitis seven applications of the Cu_2SO_4 cataphoretic douches were given at intervals of seven or eight days, three grains to one quart, sp. gr. 1002 . . . Indifferent electrode nape of neck; current strength 3-10 m.a." For these purposes special electrodes have been devised. Dr. Cleaves also suggests that the stomach douche advocated by Rosenheim in cases of chronic gastric catarrh, gastralgia, hyper-secretion, etc., be electrised. A special electrode for that purpose is in course of construction. A suitable electrode has also been made for applying hydro-electric applications of the constant current 3-10 m.a. to the face "in acne comedones and general malnutrition of the skin." When cataphoretic douches are used with copper sulphate, bichloride of mercury, zinc sulphate, etc., Dr. Cleaves says that "even with a high electromotive force, say 90 volts, the douche, whether vesical, vaginal, rectal, or nasal, will only give 3-10 milliampères."

CHAPTER X.

CATAPHORESIS.

Cataphoresis usually denotes the movement onwards of a liquid or of a semi-solid under the directional influence of an applied electric current. From a medical standpoint it presents itself under two aspects. (1) During the passage of an electric current there is a transference (a streaming movement) of the fluids of the tissues from one part of the body to another in the direction of the current.* (2) By means of an electric current the introduction of medicinal substances into the body through the uninjured skin can be accomplished. It is with the latter that the present chapter is mainly concerned—" cataphoretic medication "—" electro medicamental diffusion." Dealing as it does with the electric transfer of water holding medicinal substances in solution or suspension, this process is distinctly a " hydro-electric method." It can be shown that substances applied to the skin at the positive electrode traverse the skin, enter the body, and can be detected in the secretions or excretions. It is for the most part a process of ad-cathodal transference. As experience and experiment gradually

* This fact probably explains some of the physiological effects of electric currents.

develop its capabilities this method grows in importance and may already be considered recognised and established.

For the history of what is known of the process it is necessary to go back to the beginning of the present century. In 1807 Reuss demonstrated the electrical transfer of liquids through a porous septum and in "The Annals of Philosophy," 1817, Porret showed that when a galvanic current is conducted through the living fresh sarcous substance the contents of the muscular fibre exhibit a streaming movement from the positive towards the negative pole (as in all fluids) so that the fibre swells at the negative pole. The same thing, or something very like it, has been known, described, and discussed under many different names: "electric endosmose," "electro-capillary phenomena," "electro-vection," "electro filtration," "anodal and cathodal diffusion." In 1833 Fabré Palaprat suggested the introduction of potassium iodide through the skin by this means. In 1845 Napier read a paper on the subject before the Chemical Society, and after him many observers, notably Wiederman, Freund, and Helmholtz, have studied its phenomena and announced its laws. In 1859 Sir B. Richardson described a process of inducing anæsthesia by narcotics, anodynes, and electricity, which he called "voltaic narcotism." Unfortunately, however, and now it would appear on evidence altogether insufficient, he abandoned his position. During quite recent years in Europe and still more in America the subject has excited

renewed interest. This seems to date from experiments by Peterson and Morton, and a paper read by Dr. Cagney before the Harveian Society in 1889. At the meeting of the American Electrotherapeutic Association in 1892, a most instructive discussion took place, in the course of which Mr. Kenelly explained that, given a definite porous septum and liquid in its pores, the total quantity of liquid electrically transferred depends on the total quantity of electricity passed. The extent of the surface of the septum does not affect the result. "A current of one ampère will apparently transfer as much fluid cataphoretically through a square inch as through twenty square inches in the same time." Neither does the thickness of the diaphragm make a difference. For any electrical transfer, however, the amount of liquid transferred depends upon the substance of the diaphragm, the size and number of its pores or channels, the nature of the solution, and particularly upon the solution's resistance. But before this a paper by Edison read at the Berlin International Congress, 1890, had already brought the question even more prominently forward. Much experimental work was there detailed, and it was explained how the point had been put to the test by applying the process to a healthy person in the following way:—Two jars were arranged, one containing a 5 per cent. solution of lithium chloride with the positive pole, the other a solution of common salt with the negative pole. A current of 5 m.a. was passed for two hours daily for ten days. The urine collected during that period distinctly showed

the presence of lithium, whilst before the experiment only a trace of that substance could be detected. It does not seem to be recorded that the converse experiment was carried out, *i.e.*, with the solution of lithium and without the current, but the demonstration was nevertheless considered conclusive. The introduction of a drug into the body was in point of fact here effected by means of "a local medicated hydro-electric bath." In the treatment of syphilis it has been found by Gärtner and Ehrman, and other observers, that by adding bichloride of mercury to an ordinary hydro-electric bath through which a current of 100 m.a. was passing the specific action of the drug could be obtained. Indeed its presence was detected in the urine after the current had passed for about fifteen minutes. Gout has been treated by various lithium salts introduced in this way and their presence demonstrated in the urine. In certain obstinate skin affections, especially those of parasitic origin, mercury bichloride has been in this way successfully used after the failure of other remedies. In ringworm of the scalp (Herpes circinatus), a solution of the bichloride on the anode has been followed by cure. Experimenting upon a piece of exsected muscle with 80 m.a., and a solution of chloride of lithium, Labatut succeeded in passing $\frac{6}{10}$ of the dissolved drug into the muscle within an hour. In practice the process may be carried out by electrodes covered with blotting paper or other absorbent material applied to the skin, or by immersing parts of the body in medicinal solutions (local medicated hydro-electric bath), or by

the general hydro-electric bath. The positive electrode must be in contact with the solution it is desired to pass, and be only sufficient in size to cover the area to be influenced. The negative electrode must always be much larger than the other, and the current must not be reversed as, in order to prevent polarisation, is sometimes recommended. To reverse the current is usually to reverse the onward progress of the drug. Polarisation due to the current can easily be overcome by simply increasing the current strength. Supposing a superficial neuralgia the disease to be dealt with, and a ten or twenty per cent. solution of hydrochlorate of cocaine the drug to be used. Soak the positive electrode with the solution and let the negative electrode of large size be so placed that the part to be acted upon lies in the direct line of current flow. Use about 15 m.a. of current, for a time varying from twenty to forty minutes. The drug will find its way from the positive towards the negative pad by "mechanical transference" ("cataphoresis"). Here there is also another action, viz., ionic transference. The cocaine taking the place of the alkali in the salt, will pass from positive to negative pole electrolytically, *i.e.*, there is the electrolytic arrangement of particles, according to the well-known law "the migration of the ions" aiding the cataphoretic action. The same holds good of bichloride of mercury, citrate of lithium, and aconitine. The base as the electro-positive element travels from anode to cathode.

If neither the general nor local bath nor douche

be used for the purpose, any flat nickel-plated electrode, covered with blotting-paper to absorb the medicated solution, may be used. Mr. Peterson, of New York, recommends an electrode which is round and flat, two or three c.m. in diameter, and provided with a narrow soft rubber rim to prevent evaporation.* For convenience, and in some measure to ensure accuracy of dose, he has had the following cataphoretic discs prepared :—Menthol, two grs.; helleborine, $\frac{1}{25}$ gr.; strychninæ nit., $\frac{1}{32}$ gr.; iodol, two grs.; corrosive sublimate, $\frac{1}{8}$ gr.; cocaine hydrochl., $\frac{2}{5}$ gr.; aconitine, $\frac{1}{64}$ gr.; pot. iod., four grs.; lithium chloride, four grs. It will be obvious from the foregoing that the object of using large electrodes such as baths, local or general, is to secure, not a greater extent of mere surface, but a larger number of pores or channels, as well as to obtain the advantage of being able to use a large current, yet not too dense for easy tolerance. It may be repeated that the amount of material transferred is in proportion, not to the size of the septum, but to the number of pores or channels, as well as to the intensity of current and the "resistivity" of the solution.

The fact must not be overlooked that besides the action of the drug there is also to be considered the concomitant action of the electric current, and the independent influence of the latter for better or for worse must always be reckoned with.

As objections to the method there have been

* Dr. Morton also has devised electrodes and medicated discs well adapted to the purpose.

urged—(1) Its slowness; (2) Its inaccuracy. The former in comparison with the process of swallowing a drug is obvious. The second drawback is not special to this particular process. Supposing that with the object of influencing a special organ or a special gland five or ten grain doses of potassium iodide be administered by the mouth. With what approach to accuracy is it possible to estimate the amount of that drug that will influence the affected part? The advantages claimed are chiefly two—(1) Medicines thus introduced into the body close to the area of their expected influence must often act at a certain advantage. It is here not quite the same as with a hypodermic injection. The medicinal substance is not merely introduced and then abandoned to its chance of diffusion in the tissues, but it remains during the whole process under the strong directing influence of the cathode to localise and to concentrate its action. (2) The destructive effect of drugs on digestion is avoided. Medicinal dyspepsia is by no means a thing of the past, but there is in modern therapeutics a wholesome tendency to singleness in prescribing. That combination of remedies known as a "mixture," and in America as "shotgun therapeutics" (many pellets being put in in the hope that one may hit the mark), is scarcely holding its own against the more simply-constituted tabloid or the hypodermic injection. It will be a still further step towards the emancipation of the stomach when drugs can be introduced swiftly and surely through the uninjured skin.

A variety of cataphoretic medication which is fast

growing in repute must be noticed here. It consists in the electrolysis of a chemical solution or of a metal, and the passing of the product of the electrolysis onward into the tissues by the cataphoretic action of the current. Thus, the solution of a medicinal substance in a bath or injected into a cavity is decomposed by the current, and the product, perhaps after forming other combinations, is transferred into the subjacent tissues by cataphoresis —"interstitial electrolysis." Or a metallic substance, for example, a zinc or copper electrode placed in contact with a part is electrolytically decomposed, and the product of the electrolytic decomposition and fresh combination is driven into the subjacent tissue by cataphoresis—"metallic electrolysis." The nature of the latter process is seen in such a case as the following: An obstinate post-nasal catarrh presents itself. After being "cocainised" with spray a bulbous copper electrode attached to the positive pole is passed through the mouth to the affected part (the indifferent electrode being at the nape of the neck) and a current of 5-8 m.a. is passed. The metal is oxidised, and chlorine (evolved from the decomposition of the tissues) forms with the copper a secondary salt, the oxychloride of copper which is diffused into and over the affected part. There is both electrolysis of the metal and cataphoretic transfer of the newly-formed substance into the tissues.

One of the most energetic and original workers in this field is Dr. Morton, of New York. The following is an extract from a paper read by him before the

American Electrotherapeutic Association, 1894:—"It matters not whether the medicine in solution be applied by a sponge or blotting paper against the skin (cataphoric medication), be held in solution in the water of an electric bath (again cataphoric medication), be injected into a cavity and decomposed, be dissolved by the action of a current off a needle perforating the tissue (metallic electrolysis), or be dissolved from an electrode held in contact with mucous membrane (also metallic electrolysis), the result is the same—a foreign substance in solution, viz., a medicine, is caused to enter and permeate the tissue. It therefore seems to me to be a proper time to generalise the entire facts under the term of 'electric medicamental diffusion.'" It was Dr. G. Gautier, of Paris, who first devised the methods in question, and used the terms "interstitial" and "metallic" electrolysis. He explained that whether an oxidisable electrode of copper be attached to the positive pole of a continuous current, or a solution of potassium iodide be decomposed by the anode, in either case it is "interstitial electrolysis." He further pointed out that with oxidisable electrodes thus used there is no destruction of tissue, but that there is instead merely a decomposition giving rise to new compounds which, according to the direction and intensity of the current, are diffused into the tissues. With iron there is produced an oxide, with zinc and copper a chloride and an oxychloride. He mentions oxidisable electrodes of copper, zinc, iron, manganese, aluminium, etc., but seems to consider copper the most generally useful.

It has been necessary to enter at some length into the whole subject of interstitial electrolysis in order to explain that portion of it which is strictly hydro-electric, viz., the filling a bath, or a cavity of the body, by the solution of a metallic salt, the decomposition of the latter by electrolysis, and the passage of the products of decomposition, perhaps after forming new combinations, into the tissues by cataphoresis.

CHAPTER XI.

ON THE SELECTION OF CURRENT.

In the employment of an energy so formidable it is above all things necessary to keep always in view the old Hippocratean precept, *primo non nocere.* The first duty of the physician is not to do harm. Applied especially to electricity, there is the almost equally classic aphorism of Beard and Rockwell, "Better much too little than a little too much." In other words, any and every form of electricity must be chosen with care and handled with discretion. The selection of current demands a careful exercise of judgment. Nothing is more false than the idea that electricity is an agent simple in its nature and uniform in its effects. Everything depends upon the modality in which it is employed. A continuous current differs widely from an alternating one in its action on living tissue, and the same is true of all the various manifestations of electrical energy that have been considered. A judicious selection of current must be followed by its not less careful application. This is especially true of the large currents used in the electric bath. In selecting currents for the purposes in question it is necessary to be guided by the same practical and theoretical considerations that apply to other elec-

trical treatment. Of such considerations the following are a few :—

(1.) The operator must have his current under safe, easy, and complete control. This is theoretically obvious, and practically easy to secure. Yet in point of fact it is seldom found. It is nothing unusual to learn that patients are deterred from electrical treatment by the fear of "shocks." It seems to be assumed that shocks form a necessary part of all electrical treatment. The medical man will do well to disabuse his own mind of this idea, as well as the mind of his patient. The latter may be very confidently assured that it is only in rare cases, and never without due warning, that any proceeding which even amounts to pain need be resorted to; that "shocks" are generally harmful, and always unnecessary; that they point to a crude procedure, to a coarse instrumentation, or to an operator ignorant of how to handle an electric current.

(2.) A strong (100 m.a.) continuous current of considerable density is probably injurious to living tissue, and depresses its nutrition, whilst a mild current (five to eight m.a.) doubtless stimulates and improves nutrition. Thus, in dealing with a neuritis, a muscular atrophy, diseases of the cord, a strong current will assuredly make bad worse. In such cases, where large surfaces have to be acted upon, and a current of any considerable density carefully avoided, a generalised application by the widely-diffused current of the water-bath presents obvious advantages. On the

other hand there are cases of local thickenings of tissue, fluid exudations, fibrous adhesions, peri-articular mischief, and other post-rheumatic conditions of a chronic nature where the effects of general electrisation are not sought, but where an effect is required on certain special parts, and on them alone. Here, if pain be absent, a strictly localised action with strong, dense currents, and a preponderance of the cathode is indicated.* In this case the indication is a purely local one, and the general bath is clearly not the best method to secure it. At the same time, the possibility of effecting local results by generalised applications must not be lost sight of.

(3.) In the case of alternating currents, apart from their influence on nutrition to be presently considered, two classes of effects are usually sought —(*a*) The familiar one of muscular contraction ; (*b*) The less understood but perhaps not less valuable one belonging to the fine wire coil of a sedative or "numbing" influence.

(4.) The frequency of alternation must be considered. A muscle-contracting current, with a very slow rate of alternation, will produce contractions isolated and distinct. With a greater frequency (say five to ten a second) the individual contractions show a tendency to run into each other. With interruptions yet more frequent the muscle becomes tetanised. This excitant action increases until a rate of about sixty interruptions a second is reached. Then, if the current be a mild one, this effect begins to decrease at about the same

* Morton.

rate, until at very rapid rates the muscle ceases to respond, and a sedative effect is produced on the sensory nerves. At 120 to 150 a second such a current is no longer felt, yet still it produces a sedative or anæsthetic effect. In other words, under the use of the faradaic current excitant effects gradually increase up to a certain rapidity of interruption, and then steadily diminish. Moderate faradisation of a muscle — say five to thirty impulses a minute—like moderate exercise, and perhaps in some other way, will produce increased growth and quality in the muscle. Excessive or rapid stimulation will, like over-fatigue from any other cause, produce exhaustion and atrophy. Currents used in the faradaic bath will usually stop short of muscle contraction, at least, for any prolonged period.

It is clear that with a muscle contracting current, and interruptions at 20 to 50 per second as in the ordinary coil, the muscle would be tetanised and soon become exhausted. Looked at in this light, it is appalling to think of the tetanising currents habitually used in the treatment of the various forms of paralysis. Such currents, instead of improving nutrition and coaxing back the functional activity of a part, run the gravest risk of extinguishing the last flicker of neuro-muscular excitability. The axiom that the function of an electrical current is merely to keep a paralysed muscle exercised until the recovery of its power has in this respect something to answer for. Electrical gymnastics are no doubt useful, and often perhaps are

the chief means of improving the nutrition of a muscle, but a localised electric current undoubtedly exercises a trophic influence thereon, even in the absence of contraction.

The experiments of Debedat* made on the hamstring muscles of rabbits are instructive on this point :—(1) When this group of muscles on one side was stimulated during twenty successive days for four minutes a day by induction coil currents lasting for one second and followed by intervals of one second, there was found on the animal being killed and comparison made with the other leg a gain of 40 per cent. in weight, due to a true growth of muscle. (2) The same muscles stimulated in the same way by a rhythmic battery current of 2 m.a. showed a gain of 18 per cent. (3) Stimulated by electrostatic sparks 2 to 3 m.m. long there was no appreciable result. (4) Tetanisation with an induction coil without intervals of repose caused a loss of weight accompanied by histological evidence of deterioration. (5) Galvanic currents for four minutes without interruptions produced slight increase in weight, as well as adhesions between the skin and muscle at the point of application of the electrodes.

The experimenter therefore concluded : (1) That the mode of action of electricity on the nutrition of muscles is complex, and that under the form of continuous current it aids nutrition in some way other than as an excitant of contraction. (2) That in so far as contraction is produced it acts like

* "Archives d'électricité médicale," Feb. and March, 1894.

ordinary exercise, but presents certain advantages over the latter from a therapeutic point of view. (3) Moderate exercise produced by rhythmic faradaic currents give the best results. (4) The results of rhythmic galvanic currents are inferior to the above, but superior to the continuous galvanic current. (5) Prolonged tetanisation by faradaic currents as detailed above produces exhaustion and atrophy. (6) The static spark produces no lasting change.

When it is desired, as will usually be the case in employing the electric bath, to influence the nutrition of the whole body, the following physiological data (d'Arsonval's experiments) will be of service :—

Effects on General Nutrition.—(*a*) The faradaic current (general faradisation) leads to an increase in the respiratory exchanges by excitation of the muscular system and also of the sensory nervous system; in other words, the nutritive exchanges are increased either with or without muscular contractions.

(*b*) The continuous current (galvanic), which has always been considered as *par excellence* the current of nutrition, produced no appreciable influence on the respiratory combustions. To explain its trophic effects, therefore, it has been surmised that these may be the result of an influence on cellular secretion or other process.

(*c*) Sinusoidal currents afford the most striking results. Without any excitation of the neuro-muscular apparatus, and in the complete absence of pain, there was a notable difference in the intake

of oxygen and the output of carbon dioxide by the lungs. In point of fact, the respiratory exchanges were increased by twenty-five per cent. Rapidity of alternation as influencing the physiological effects of sinusoidal currents was also studied by the same experimenter; his results are given as follows* :— As frequency is gradually increased, neuro-muscular excitation goes on increasing until 2,500 to 3,000 excitations a second are reached. Between 3,000 and 5,000 the excitant effects do not alter, but above this rate they go on decreasing up to 10,000. The results already recorded (page 60) of the therapeutic uses of sinusoidal currents are in accord with the physiological data just stated, and perhaps point to this form of current as likely to be effective in a larger number of cases than either the continuous current or the dissymmetrical alternating one. But this is not yet proved, and the "faradaic bath" is by no means yet deposed from the position of usefulness it has so long occupied.

The above experimental data form the starting point of that field of modern practice which aims at the treatment of diatheses and of general conditions of the system; and this by the generalised, rather than by the localised, action of electric currents. It need not be again pointed out that there is no method by which such an action can be more effectually secured than through the medium of the water bath.

* "Rev. Int. d'Electrothérapie, May, 1893.

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